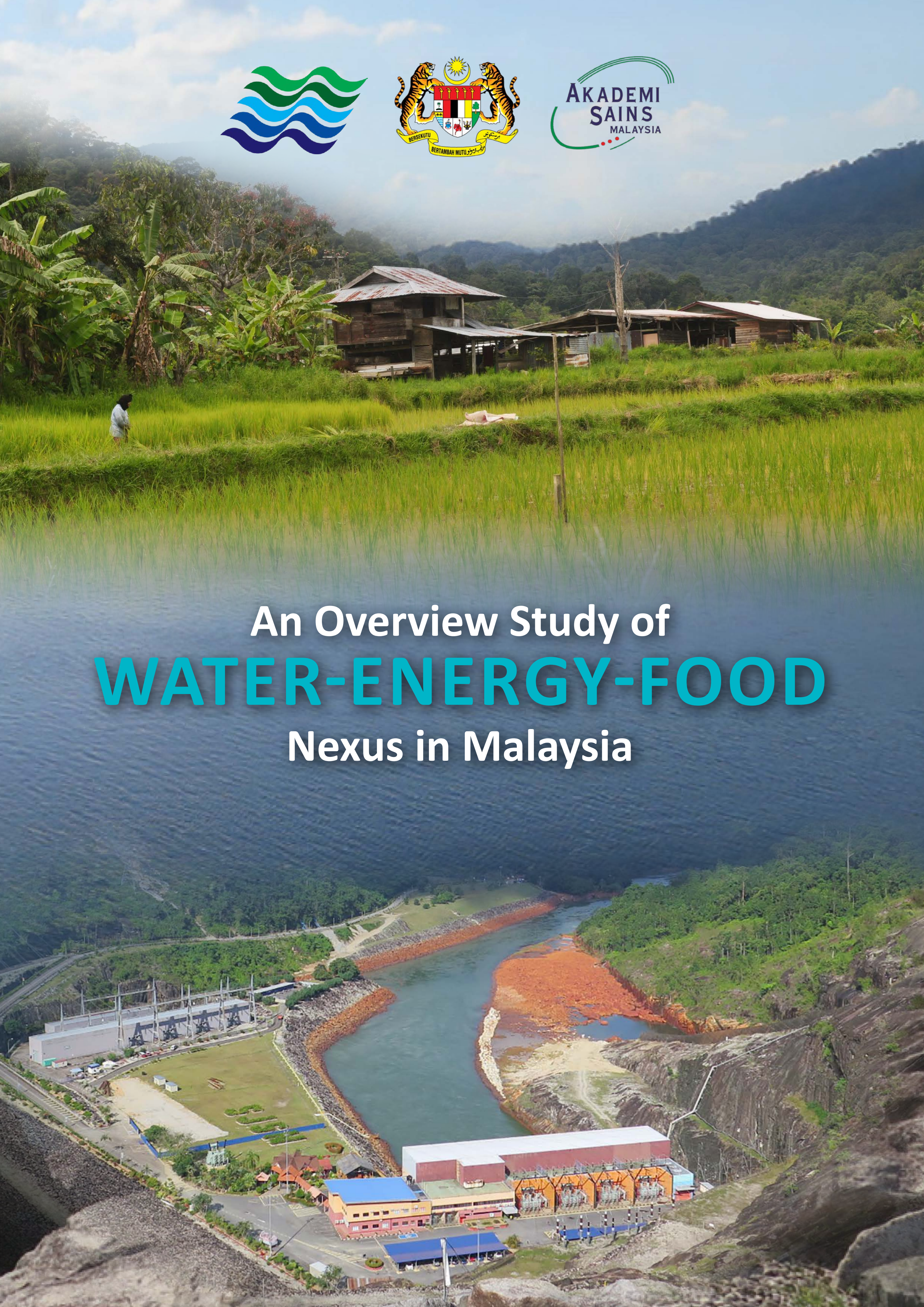


# An Overview Study of WATER-ENERGY-FOOD Nexus in Malaysia

# An Overview Study of WATER-ENERGY-FOOD Nexus in Malaysia

A Report Commissioned by the
Department of Irrigation and Drainage (DID) Malaysia

## COPYRIGHT



ISBN 978-983-9304-4-11

## DISCLAIMER

The opinions expressed in this publication are those of the author and do not necessarily reflect the views and policies of the Department of Irrigation and Drainage. The Department does not guarantee the accuracy of the data included in this publication and accept no responsibility for any consequences of their use.

## ABOUT THE AUTHOR

Adnan A Hezri is an elected Fellow of the Academy of Sciences Malaysia. He is also a Senior Director at the Institute of Strategic and International Studies Malaysia. His specialisation is comparative policy spanning areas such as natural resources governance, green economy, and sustainable development strategy. Hezri holds a PhD in Public Policy from the Australian National University, where he is currently Honorary Associate Professor.

## CITATION

Hezri, A.A. 2018. *An Overview Study of Water-Energy-Food Nexus in Malaysia*.
The Department of Irrigation and Drainage; Kuala Lumpur.

# CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# ACRONYMS

| | |
|---|---|
| ASEAN | Association of Southeast Asian Nations |
| DOA | Department of Agriculture |
| DOE | Department of Environment |
| EPU | Economic Planning Unit of Prime Minister's Department |
| ESA | Environmentally Sensitive Areas |
| EQA | Environmental Quality Act 1974 |
| FAO | United Nations Food and Agriculture Organization |
| GHG | Green House Gases |
| IADA | Integrated Agriculture Development Area |
| IPP | Independent Power Producers |
| IPCC | Inter-Governmental Panel on Climate Change |
| IWRM | Integrated Water Resources Management |
| JPBD | Jabatan Perancangan Bandar dan Desa (or Town and Country Planning Department) |
| JPS | Jabatan Pengairan dan Saliran (or DID, Department of Irrigation and Drainage) |
| KADA | Kemubu Agricultural Development Authority |
| LUAS | Lembaga Urus Air Selangor (or Selangor Water Management Authority) |
| MDG | The Millennium Development Goals |
| MLD | Million litres per day |
| MW | Megawatt |
| NAWAB | National Water Balance Study |
| NAHRIM | National Hydraulic Research Institute Malaysia |
| NWRP | National Water Resources Policy |
| PERHILITAN | Jabatan Perlindungan Hidupan Liar dan Taman Negara (or Department of Wildlife and National Parks) |
| PETRONAS | Petroliam Nasional Berhad |
| SEB | Sarawak Energy Berhad |
| SESCO | Sarawak Electricity Supply Corporation |
| SSL | Self-sufficiency levels |
| STP | Sewerage treatment plants |
| TNB | Tenaga Nasional Berhad |
| UN | United Nations |
| UNESCAP | United Nations Economic and Social Commission for Asia and the Pacific |
| WEF | Water-Energy-Food |
| WTP | Water treatment plants |

# FOREWORD

Water, energy, and food systems are interconnected. In reality, however, these resource systems are managed separately. The Nexus is where and how these three systems intersect. Because actions related to one system can impact one or both of the other systems, it is necessary to take Nexus Approach to avoid future resource insecurities.

Like many other countries in the world, Malaysia has and is currently facing many challenges with strained water, energy, and food systems. This situation necessitates a shift in thinking to understand that what we do every day affects the WEF nexus and the nexus, in turn, affects our daily life. A reliable supply of water, energy, and food is one of the most critical global challenges of the present time and the future, and we know that the WEF nexus will help holistically manage the three resource systems.

The report titled *An Overview Study of Water-Energy-Food Nexus in Malaysia* highlights the interdependencies of the water, energy, and food sectors in the context of development in Malaysia at various scales of governance. It builds on and extends the previous work by the Department of Irrigation and Drainage Malaysia (DID) in the area of Integrated Water Resources Management (IWRM).

As a preliminary analysis of trade-offs and synergies of WEF nexus in the country, I hope that the report will encourage a more detailed assessment from the scientific community to understand the challenges of resource scarcity that Malaysia is or will be facing. Similarly, I also hope all stakeholders in the three sectors to engage in dialogue and work together to address the challenges and tap on the opportunities. Systematically and proactively addressing the nexus will help us all to secure water, energy, and food resources for Malaysia.

It is my humble wish that this publication will serve as a useful and convenient reference to individuals involved in mitigating water-related hazards and disasters for a sustainable future.

**Dato' Ir Hj Nor Hisham bin Ghazali**
Director
Division of Water Resources and Hydrology
Department of Irrigation and Drainage Malaysia

# ACKNOWLEDGEMENTS

This report was prepared by Dr Adnan Hezri from the Academy of Sciences Malaysia with funding from the Department of Irrigation and Drainage (JPS), the Ministry of Natural Resources and Environment Malaysia (currently Ministry of Water, Land and Natural Resources). It would not have been possible without the input and guidance from numerous agencies representing the different stakeholders of water, food and energy resources. Their names and affiliations are listed below, based on consultations undertaken from October to December 2015. The leadership of Hj Juhaimi Jusoh, the Director of JPS Perak (then Deputy Director of Water Resources and Hydrology, JPS) in the conceptualisation and the conduct of the study is duly acknowledged herein. The author would also wish to thank Ms Ainun Jaabi and Ms Michelle Kwa from the Institute of Strategic and International Studies (ISIS) Malaysia as well as Malvina Anthony for their technical assistance in the preparation of this report.

## National Level Informants

| | | |
|---|---|---|
| 1 | Hj Juhami Jusoh | JPS Malaysia |
| 2 | Norashikin Abdullah | JPS Malaysia |
| 3 | Ir Mohd Razali Husain | JPS Malaysia |
| 4 | Dato Ir Hj Hanapi Mohamad Noor | JPS Malaysia |
| 5 | Mohd Khanil Taib | Tenaga Nasional Berhad (Major Projects) |
| 6 | Hj Zolkifle Abdul Hamid | Tenaga Nasional Berhad (Generation) |
| 7 | Tan Sri Shahrizaila Abdullah | Academy Sciences Malaysia |
| 8 | Tan Sri Dr Tajuddin Ramli | Academy Sciences Malaysia |
| 9 | Dr Ir Salmah Zakaria | Academy Sciences Malaysia |
| 10 | Loh Chia Hor | Academy Sciences Malaysia |
| 11 | Vishalini Arumugam | Economic Planning Unit |
| 12 | Azaman Md Ali | Ministry of Agriculture |
| 13 | Ahmad Fazili Abd Hamid | Ministry of Agriculture |
| 14 | Md Nazley Othman | JPS Malaysia |
| 15 | Ir Hj Nishad Mohamed Hj C. J. Mohd Shaffy | JPS Malaysia |
| 16 | Wan Syamsafariza Izawane Wan Mohd Fikri | JPS Malaysia |
| 17 | Mohd Erwan Miswan | Ministry of Natural Resource and Environment |
| 18 | Nur Zawani Ibrahim | Ministry of Natural Resource and Environment |
| 19 | Lee Chin Shyan | National Water Services Commission |

| | | |
|---|---|---|
| 20 | Dato' Dr Mohamad Zahari B Abdul Ghani | MARDI |
| 21 | Azmir Firdaus Zamzuri | Jabatan Pertanian Selangor |
| 22 | Dr Vijaya Subramaniam | Malaysian Palm Oil Board |
| 23 | Abd Khadir Abd Aziz | JPS Malaysia |
| 24 | Hairul Anuar Muhammad | JPS Malaysia |
| 25 | Mohd Jais Tambi Hussein | JPS Malaysia |
| 26 | Ismail Faruq | Tenaga Nasional Berhad |

**Informants for the Sg Perak Basin Case Study**

| | | |
|---|---|---|
| 27 | Ir Hj Hidzrami Shamsul Anwar | JPS Perak |
| 28 | Khisuri Mohd Din | JPS Perak |
| 29 | Ir Rosazlan Abu Seman | JPS Perak |
| 30 | Saidan Abu Hasan | Tenaga Nasional Berhad (SJ Sg Perak) |
| 31 | Mohd Farid Jafre | Tenaga Nasional Berhad (SJ Sg Perak) |
| 32 | Hasbullah Abd Aziz | Tenaga Nasional Berhad (SJ Sg Perak) |
| 33 | Madelina Anak Cosmas Panggie | IADA Seberang Perak |
| 34 | Nur Syafawati Sulaiman | IADA Seberang Perak |
| 35 | Ahmad Shokhaily | IADA Seberang Perak |
| 36 | Mohd Termizi Mohd Noor | IADA Seberang Perak |
| 37 | Meor Shahimudin Hj Hashim | Jabatan Pertanian Perak |
| 38 | Ishak Abd Rahman | Lembaga Air Perak |
| 39 | Muhammad Fazil | Lembaga Air Perak |
| 40 | Ir Rozali Haron | Lembaga Air Perak |
| 41 | Ir. Haji Wan Amil Abas Wan Omar | Lembaga Air Perak |
| 42 | Azizah Mohd Sabri | JPS Perak Tengah |
| 43 | Mohamad Amin B Azahari | JPS Manjung |
| 44 | Kamarudin Yacob | JPS Hilir Perak |

**Informants for the Sg Bernam Basin Case Study**

| | | |
|---|---|---|
| 45 | Ir Azmi Abu Samah | IADA Barat Laut |
| 46 | Mohd Shawal Abd. Wahid | IADA Barat Laut |

**Informants for the Sg Kelantan Basin Case Study**

| | | |
|---|---|---|
| 47 | Hasmira Hamid | JPS Kelantan |
| 48 | Hasmida Hamid | JPS Kelantan |
| 49 | Marziah Mohamad | JPS Kelantan |
| 50 | Zulkifli Hamzah | JPS Kelantan |
| 51 | Yushairo Yusoff | JPS Kelantan |
| 52 | Siti Zakirah Baharom | JPS Kelantan |
| 53 | Ir Tn Hj Shahimi Shariff | JPS Kelantan |
| 54 | Mohd Zulkifli Ahmad | JPS Kelantan |
| 55 | Safuandzi Abdullah | JPS Tanah Merah |
| 56 | Izani Abdul Rahman | JPS Jeli |
| 57 | Ahmad Tarmizi Mat Taib | JPS Tumpat |
| 58 | Mazlan Md Saleh | JPS Malaysia |
| 59 | Wan Zamri Wan Hamat | Air Kelantan Sdn Bhd |
| 60 | Mohd Safrurazi Salleh | Air Kelantan Sdn Bhd |
| 61 | Ir Nazri Hamzah | IADA Kemubu |
| 62 | Rahim Isa | KADA |
| 63 | Wan Nasharuddin Hj Wan Abdullah | KADA |
| 64 | Ir Shoksi Che Nur | KADA |
| 65 | Darul Hisham Saman | Tenaga Nasional Berhad |
| 66 | Mohd Mazlan Mat Zain | Tenaga Nasional Berhad (SJ Pergau) |
| 67 | Rohani Jusoh | Department of Agriculture Kelantan |

# 1 INTRODUCTION

## 1.1 EMERGING CHALLENGES

We live in an increasingly interconnected world. The speed and magnitude of global change, the increasing connectedness of the social and natural systems at the planetary level, and the growing complexity of societies and their impacts upon the biosphere result in high and expanding levels of uncertainty and unpredictability. The major issues facing our planet are of a magnitude that no one institution or organisation can address on its own. The list includes demographic imbalance, terrorism, climate change, mass migration, illicit trade, and emerging diseases, just to name a few.

The intensification of economic, social, political, and cultural changes and their interlocking effects have also led to the systemic challenge of natural resources insecurities. If not tackled well, such insecurities may become impediments to social stability and economic growth. In 2050, with a forecast 9.2 billion people sharing the planet, it is expected that there will be a 70 per cent increase in demand for food and a 40 percent rise in demand for energy (Hoff, 2011). Further, by 2030, the world will have to confront a water supply shortage of about 40 percent.

Thus, water, food, and energy resources are tightly interconnected, forming a policy nexus (Vogt et al., 2010). Food production is the largest user of water globally. It is responsible for 80–90 percent of consumptive water use from surface water and groundwater. Water, however, is also used to generate electricity, and about 8 per cent of global water withdrawal is used for this purpose. Energy, in turn, is needed to transport and fertilize crops. Food production and supply chains are responsible for around 30 percent of total global energy demand. Crops can themselves be used to produce biofuels (Hoff, 2011). If we aim for a sustainable and inclusive future, the current 'business-as-usual' economy is no longer a viable model of development. We cannot run on the same finite water, energy and food resources far into the future (Bleischwitz et al,2018).

Although this nexus presents new threats, it also offers new opportunities for humankind. A redefinition of policy framing on natural resources management is currently taking place to tackle the emerging challenges, and the nexus thinking guides it. The Global Resource Nexus report by the Transatlantic Academy argues that the nexus approach allows a systemic consideration of potential impacts from resource utilization (Andrews-Speed et al., 2012, p. 2):

> "The range of potential risks and uncertainties relating to a single resource is magnified when the links between different resources are taken into account."

Without considering interconnections, resource allocation may easily become a zero-sum game where intense competition for resource access can quickly become a conflict. Moreover, despite the close relationship of energy, water, and food resources different people in separate agencies typically perform the funding, policymaking and oversight of these resources. This 'silo' may lead to negative trade-offs impacting policy and technological choices. Of all natural resources, water, food, and energy are most needed to sustain life on earth. These three resources share many comparable characteristics: there are billions of people without access to them; they have a rapidly growing global demand; all face resource constraints; all three are "global goods" involving international trade with global implications; each has different regional availabilities and variations in supply and demand; and all operate in heavily regulated markets (Bazillian et al., 2011). Because of these reasons, they present deep security issues as they are fundamental to the functioning of society.

## 1.2 STUDY RATIONALE

Against the backdrop of increasing demand for strategic resources, there is evidence of inefficiency and wastage in the water, energy, and food sectors in Malaysia. The volatility of resource prices and the growing acceptance of concepts such as non-stationarity and hydrosocial cycle in the water sector, all point to emerging global focus on comprehensive resource security analysis. It is therefore timely for Malaysia to reframe its framework on natural resources governance. Currently there is only rudimentary understanding of the complex and pervasive connections between water, food and energy security in Malaysia.

### 1.2.1 Prices Volatility and Multiple Scarcity

Prices of natural resources are dependent on many variables. Contrary to the mainstream economic view, physical scarcity is not alone in influencing prices. The determinant for prices volatility for non-renewable resources may be attributable to technological change, the discovery of new deposits, the stability of imports and export, and government tampering with the market along the supply chain. Indeed, beyond economic and physical scarcity, scholars have also discussed political, environmental and equity dimensions of scarcity (Andrews-Speed et al. 2015). Most resources are asymmetrically distributed across the globe, begging the question of secure access and its governance.

The shortage of land, water, and food is probably more severe than resources such as non-critical minerals or even oil and natural gas. Food prices are always tightly linked to the prices of crude oil. When oil prices spiked in 2007-2008, food prices rose concomitantly. This increase is not surprising because agriculture is known to be energy-intensive through increased use of machinery, fuel for transportation and water pumping. Also, oil prices also impact food prices because fertilizers, pesticides and other essential farm inputs are derived from petroleum.

While the slump in global oil prices since 2014 has brought cheaper food to the world's poorest, the benefits are not universal. Low oil prices may hamper economic activity in the net exporting countries that rely on oil revenues such as Saudi Arabia, Iran, Russia, Venezuela, and Malaysia. For the net oil importing countries such as China and Japan, low oil prices can bring significant savings. Some countries, Malaysia included, have used the current dip in oil prices as an opportunity to reduce their fossil fuel subsidies at a lower political cost. But the low prices could be damaging for the environment when investments in green technology dwindle and consumers drive more often to work. In any case, changes in policy levers in food and energy sectors may have a knock-on impact on the water sector and its security dimension.

### 1.2.2 Non-Stationarity and Information Uncertainty

The training and practice in water-resource engineering, planning, and risk assessment are underpinned by the idea of 'stationarity'. This approach essentially means that natural systems fluctuate within an unchanging envelope of variability (Koutsoyiannis 2006). The stationarity assumption implies that annual streamflow, precipitation or annual flood peak has a 1-year periodic probably density function whose properties can be estimated from time series data. But with increasing human intervention on natural landscapes, the underlying assumption has changed, from stationarity to non-stationarity, or uncertainty in the modeling of hydrological systems. Large-scale deforestation, river modification, drainage works, and increasing urbanisation have all changed the characteristics of hydrologic responses such as the timing and magnitude of floods.

Additionally, climate change is projected to have significant fallout upon streamflow regimes worldwide. There have been numerous hydrological modeling studies across the world carried out to assess the potential impact of climate change on hydrology, evapotranspiration, flow regimes in river basins, and water resources in general. The most important climatic projections are provided by the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2013). The IPCC model depicts a changing global water cycle, with increases in disparity between dry and wet regions. With the combined effect between the two, some analysts have gone as far as to declare that 'stationarity is dead' (Milly et al. 2008), demanding that the scientific and policy communities require new methodology of understanding changes in the flow regime in river basins as well as climate variables in the atmosphere.

Thus, when planning water supply for food production, building power plants infrastructure, designing hydraulic systems, or choosing appropriate crop varieties, it is crucial that non-stationarity of hydrologic information is sufficiently recognised and acted upon. Although these structures and systems may be locked in for decades, there may be possibilities for adaptation where and when necessary.

### 1.2.3 Hydrosocial Cycle

The term 'hydrosocial cycle', instead of the hydrological cycle, refers to the inseparable social and physical dimensions of water. The hydrological cycle points to the natural cycle of water or the water engine that is fuelled by solar energy, driven by gravity, and proceeds endlessly in the presence or absence of human activity. But water resources cannot be disentangled from human systems as was aptly argued by Bakker (2002: p.774) as follows:

> "Whereas $H_2O$ circulates through the hydrologic cycle, water as a resource circulates through the hydrosocial cycle – a complex network of pipes, water law, meters, quality standards, garden hoses, consumers, leaking taps, as well as rainfall, evaporation, and runoff. ... [W]ater is simultaneously a physical flow (the circulation of $H_2O$) and a socially and discursively mediated thing implicated in that flow..."

Therefore, we cannot manipulate water without profound social consequences. Wider ownership of the water resource problem – especially when challenged by the increasing dependencies between upstream and downstream users in a river basin – in turn, necessitates different policy processes and responses. These problems can only be mediated by governance in the context of 'hydrosocial cycle,' whereby water is a hydrosocial fact, with people and politics sitting at the centre of all water issues. Hence, the widespread but incorrect belief that water management is straightforward and can be handled within a 'water sector' has to change in Malaysia.

## 1.3 THE NEXUS APPROACH

The emerging fear of water, food and energy crisis has escalated the importance of the nexus perspective onto the international policy discourse. It now receives increasing political reference due to its strategic importance. A 2012 YouGov Poll, an online market research agency, placed ensuring continued supply to water, food, and energy as second to terrorism as a foreign policy priority in Britain (Hoff 2011). The nexus of water, food, and energy, indeed, is currently gaining attention from strategic circles in the policy and academic domain.

The securitisation of these three resources is underpinned by the idea of 'limits' which first brought about in the 1970s and 1980s. The idea did not only fade into obscurity despite its limited adoption in public policy. Rather, it is becoming more complex. For development activities to be sustainable, the following limits must be taken into account (United Nations, 2011, p. 54):

- Biophysical limits – What is possible within planetary limits and according to the laws of nature?
- Economic limits – What is affordable?
- Scientific-technical limits – What is doable technically?
- Socio-political limits – What is socially and politically acceptable?

Whereas the 'limits-to-growth' idea was mainly linked to single resources such as crude oil or minerals, the recent emphasis is targeting the scarcity of multiple resources along with their supply chain. There is increasing evidence in many other countries that improved water, energy, and food (WEF) security can be achieved through a nexus approach – one that integrates management and governance across sectors and scales. The WEF nexus approach can also support the transition to a Green Growth or

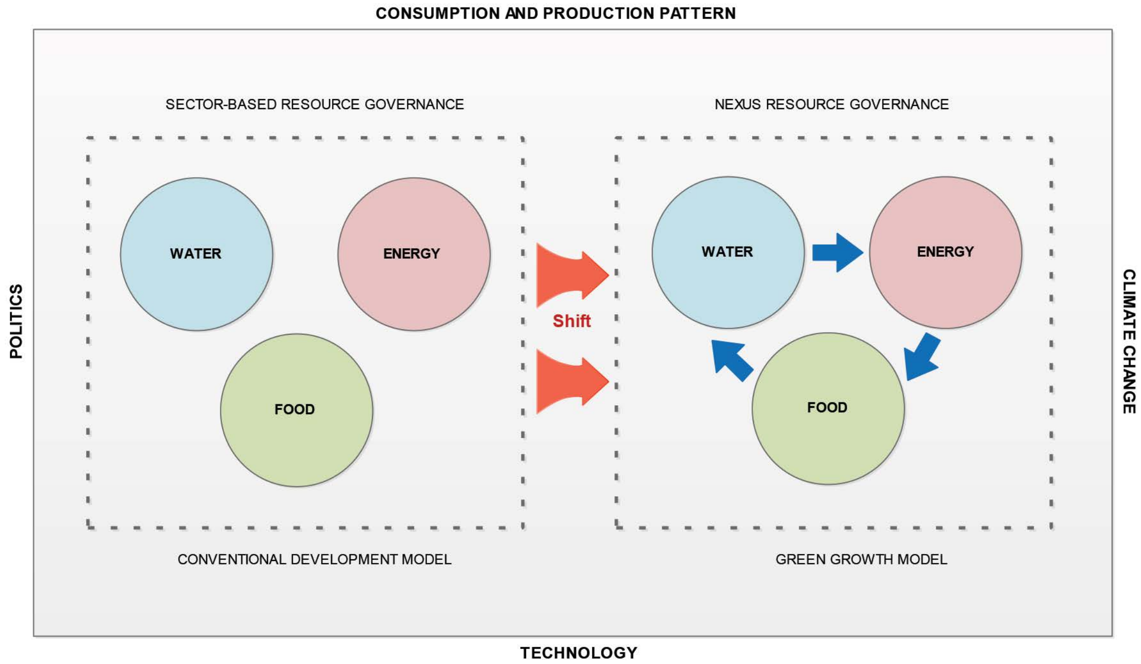



**Figure 1.1: The Nexus Approach Represents a Shift from Silo- to Integrated-Resource Management**

Green Economy, which aims, among other things, at resource use efficiency and greater policy coherence (Figure 1.1). There are many trade-offs countries such as Malaysia must cope with, and synergies to be tapped in optimising the use of different resources. Analytically, the nexus approach examines physical, technological, socio-political, and institutional connections in a more integrated manner.

A nexus assessment forces us to look ahead into our future. It is not enough to assess the nexus regarding what it means at present, but it is essential to consider what the megatrends mean for inter-sectoral dynamics in decades or longer (Hezri & Kwa 2018).

## 1.4 SCOPE AND STRUCTURE

This report presents a cross-cutting study that traces the state-of-affairs of Malaysia's strategic resources – energy, food, and water. It does so by asking the question whether Malaysia has moved from a period of resource cornucopia that fuelled its first few decades of rapid development to one that is characterized by resource scarcity.

The report is based on a 2-month desktop study designed to provide an overview of the nature of the interaction between the water, food, and energy sectors in Malaysia. Because agriculture is the largest user of water resources, this preliminary assessment focuses on the nexus interaction in the rural areas by selecting three basin-level case studies. With rapid urbanisation, domestic and industrial sectors will gradually replace the rural sector as the largest consumer of water resources. This situation will require another study with a different design and research approach.

The report provides a snapshot of the Nexus challenge at four different scales of governance. Chapter 2 provides the overview of the key concepts and initiatives on water, energy and food security nexus at the international level. Chapter 3 presents the stand-alone security challenges arising from the insecurity of water, energy, and food resources on the national scale. Chapter 4 takes a different tack by examining the consequences of the two-way or three-way nexus interactions at the state level. Before concluding with synthesis and recommendations in Chapter 8, Chapters 5, 6, and 7 analyse nexus issues in the river basins of Sg Perak, Sg Bernam, and Sg Kelantan.

# 2 GLOBAL WATER-ENERGY-FOOD NEXUS

## 2.1 BACKGROUND

The present discourse on nexus gravitates around the importance of interconnections and interdependencies of complex natural systems. Some of the most pertinent operational challenges of the nexus approach refer to the informational and knowledge gap on interconnections and their consequences. Their interactions with external forces fundamentally boils down to identifying the solutions in the implementation of integrated management policies.

### 2.1.1 Emergence of the Nexus Approach

While the recognition of close linkages between of water security and food security has been instigated in the late 1980s, there was little progress made in theorizing or understanding their synergies in the past three decades (Allan et al., 2015). "Nexus thinking" only emerged over the last decades in broader resource issues especially in the wake of the global financial crisis in 2008 and the on-going environmental crisis predominantly climate change. All economies are dependent on resource extraction and consumption to maximise well-being. Therefore, dwindling resource is posing threats to livelihood and biodiversity. Evermore, the impacts of growing resource consumption are becoming more evident and complex.

Widespread concerns over food security have emerged in both developed and developing countries following the 2007–2008 and 2011 upsurge in agricultural commodity prices. This scenario has led to "global land rush" thereby giving rise to risks such as dispossession and loss of livelihoods, corruption, deterioration in local food security, and environmental damage (Arezki et al., 2015). Similarly, access to treated water remains a key challenge largely in the developing world with an ever-increasing number of people affected by water shortages exacerbated along with climate irregularities. Energy demand soars and is projected to grow by 37 percent in 2040 while $CO_2$ emissions are expected to rise by 20 percent in 2040 putting the world on track for a long-term global temperature increase of 3.6 °C as they fall short of reaching the 2 °C target (WEO, 2014).

Following this, there is an increasing acceptance that solutions to the economic and environmental crises are the sustainable and efficient management of these resources (Bringezu & Bleischwitz 2009). The nexus approach as such is deemed crucial because decisions enhancing one area of resource security while compromising other areas are unsustainable. Recognising the interconnections among sectors at such eliminates the potential zero-sum game in resource allocation whereby intense competition for resource access can easily become conflict (Bizikova et al., 2013). Also recently, the nexus approach resonates and has become central to discussions regarding the development and subsequent monitoring of the 17 Sustainable Development Goals (SDGs) that are set to replace Millennium Development Goals (MDGs) in the post-2015 development agenda.

### 2.1.2 Multiple Resource Scarcity

Commendably, the nexus approach is relevant beyond the three-way water-energy-food (WEF) security to also include other areas such as land, minerals and climate change (see UNESCAP, 2014). Within the three water-energy-food nexus, the position of nexus and its element mainly lies on the perspective and lens of the policymakers and researchers. The WEF nexus framing is to some appear to be too restrictive (excluding climate change and nature). Some actors see it as linked to the green economy and poverty reduction, while others emphasise global scarcity and value chain management (Allouche et al., 2015). The focus of the nexus varies according to selected

**Table 2.1: Review of WEF Security Nexus**

| | |
|---|---|
| **Food security** | The elements of food security are: (1) food availability: influenced by production, distribution, and exchange of food; (2) access to food: including affordability, allocation, and preference; (3) utilization: nutritional value, social value, and food safety (4) food stability over time |
| **Water security** | The elements of water security are: (1) water access; (2) water safety; and (3) water affordability so that every person can lead a clean, healthy and productive life while ensuring that the natural environment is protected and enhanced |
| **Energy security** | The elements of energy security are: (1) continuity of energy supplies relative to demand; (2) physical availability of supplies; and (3) supply sufficient to satisfy demand at a given price |

**Source: Bizikova et al., 2013**

sectors, for instance, land at times substitutes for food and sometimes climate change is added to the nexus (see Figure 2.1). In the same way, the nexus approach has been applied in various combinations, commonly the interconnections between energy and water (Malik, 2002; Gold & Bass, 2010; Scott 2011; Siddiqi & Anadon 2011; Laldjebaev, 2012; Gu et al., 2014; Hussey & Pittock, 2015).

Arguably, all three WEF resources among others rendered significant challenges to security issues because they are fundamental to the functioning of society and they are global goods operating in heavily regulated markets that involve in international trade and have global implications. Also, other qualifying elements of WEF nexus which require the explicit identification and treatment of risks include that all three resources have (Bazilian et al., 2011):

- Many billions of people without access
- Rapidly growing global demand
- Resource constraints
- Different regional availability and variations in supply and demand
- Strong interdependencies with climate change and the environment

A paper by United Nations Economic and Social Commission for Asia and the Pacific summarises the central position of the WFE nexus in the main initiatives of international agencies (see Figure 2.1).

These different models for integration are aimed to complement conventional approaches that are limited to only improve sectoral resource productivity without factoring in the inter-linkages across sectors.

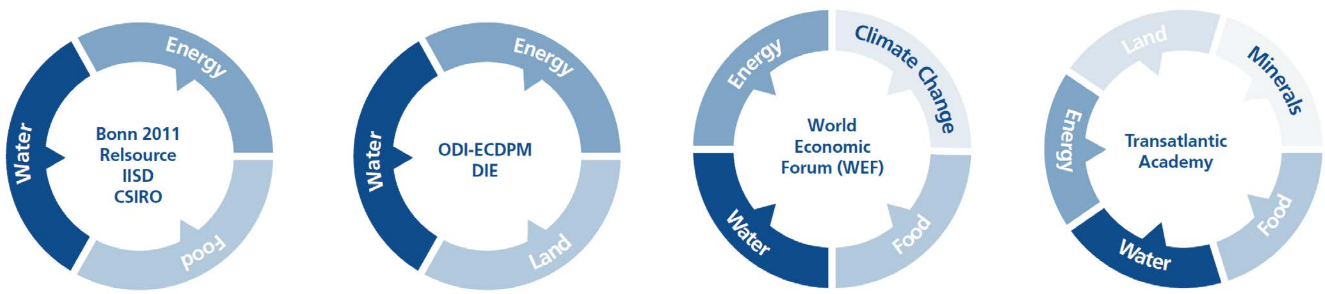



**Figure 2.1: Different Emphasis on Nexus by Various Organizations.**

**Source: UNESCAP 2014**

## 2.2 KEY IDEAS ON WEF NEXUS

The notion of "WEF Nexus" gain its ascendency in some global and regional conferences, workshops and meetings that were held in 2011–2012, especially and during the preparation phase for Rio+20 in June 2012 (see Bizikova et al., 2013). Notably, the WEF nexus is highly relevant as a conceptual tool for achieving sustainable development (Hoff, 2011; Biggs et al., 2015). One of the integrative principles of sustainable development is in its reflexivity character in integrating knowledge into policymaking through continuous monitoring and evaluation (Steuer, 2008). This principle aligns with the fundamental rationale of WEF nexus concept which is to identify "set of interconnections, trade-offs, and interdependencies existing between water, energy, and food as a result of their natural cycles and human use" (Hoff, 2011). Both integrative manner of sustainable development and WEF Nexus is a pre-requisite in achieving science-policy interface which leads to policy coherence and efficient use of resources.

While the nexus approach has been much discussed, a widely accepted definition of the WEF nexus is still missing (Allouche et al. 2015). There are quite a few interpretations and framings of WEF nexus which differ across a range of organisations, including investment-type organisations, sustainability-type organisations and research institutes, and conservation organisations, including about concepts such as sustainability, the green economy, and scarcity and trade-offs. Naturally, the defined nexus approaches are nothing short in the diversity in perspectives; some expressions come with strong sectoral viewpoints. A recurring criticism of WEF nexus approach is the questionable novelty of the solutions proposed (FAO, 2014). Although existing water-centric paradigm of Integrated Water Resources Management (IWRM) has long been recognised for its integrative approach, a critical difference is that the nexus is a multi-centric concept that addresses the different sectors of water, energy, food, and climate security.

Moreover, the nexus dynamics are different with resources with various nature, properties, cycles, and behaviour. Another caution raised on the WEF nexus is its framing that is top-down, North to South linked to external interests, and its one-size-fits-all managerial solutions (Alltouche et al., 2015).

Nonetheless, existing literature on the conceptualisations and frameworks on WEF nexus points to three crucial elements. The first point is the understanding of trade-offs between these three areas of resources. The second is the assessment of the consequences that internal and external changes in each can bring to others. The final element of WEF nexus is the generation of policy responses and actions that can address the three securities (Bizikova et al., 2013). The following sub-sections underline the various nexus-orientated approaches, frameworks and assessment tools by some institutions, networks, and organisations. These include: Hoff (2011) by the Stockholm Environmental Institute (SEI), World Economic Forum (2011), Rasul (2012) by International Centre for Integrated Mountain Development (ICIMOD) (2012), International Institute for Sustainable Development (IISD) (2013), Howells et al. (2013), Food and Agriculture Organization (FAO) (2014), World Bank (2014), University of Cambridge (2015), Qatar Environment and Energy Research Institute (QEERI) (2015). This list is by no means exhaustive but highlights some of those which have taken a holistic (rather than narrowly sectoral) method.

### 2.2.1 Approaches

The WEF nexus framework was first conceived by the World Economic Forum (2011) and later by Hoff (2011) as part of *Bonn2011 Nexus Conference on the Water, Energy and Food Security Nexus: Solutions for the Green Economy* to promote the inseparable links between the use of resources to provide core and universal rights to food, water, and energy security. While World Economic Forum (2011) presented the nexus framework from a securities perspective (water–energy–food security), subsequent versions have taken on various facets with alternative components, such as water resources as a central component (Hoff, 2011), and ecosystem goods and services as key part of the WEF framework (Rasul, 2012). In 2013, the IISD made a detailed review of

**Table 2.2: Various Frameworks and Approaches to WEF Nexus**

| Nexus approaches and frameworks | Central component | Policy response |
|---|---|---|
| Global Risks 2011 Sixth Edition An initiative of the Risk Response Network<br><br>World Economic Forum (WEF) | Securitisation resource scarcity and its associated risks | · integrated and multi-stakeholder resource planning;<br>· regionally focused infrastructure development;<br>· market-led resource pricing;<br>· community-level empowerment and implementation;<br>· technological and financial innovation for managing the nexus. |
| Bonn2011 Nexus Conference on the Water, Energy and Food Security Nexus: Solutions for the green economy<br><br>Stockholm Environment Institute:<br><br>Hoff (2011) | Water supply, energy and food security, all connected to available water resources | · increasing resource productivity;<br>· using waste as a resource in multi-use systems;<br>· stimulating development through economic incentives; implementing governance, institutions and policy coherence;<br>· benefiting from productive ecosystems;<br>· integrated poverty alleviation and green growth;<br>· capacity building and raising awareness. |
| Contribution of Himalayan ecosystems to water, energy, and food security in South Asia: A nexus approach<br><br>Rasul (2012)<br><br>International Centre for Integrated Mountain Development (ICIMOD) | The stress on ecosystem services through system-wide approach rather than a sectoral approach | · restoration of natural water storage capacity;<br>· development of climate-smart, environmentally and socially sound infrastructure;<br>· and incentive mechanisms for managing Himalayan ecosystems. |
| The water-energy-food security nexus: Towards a practical planning and decision-support framework for landscape investment and risk management<br><br>Bizikova et al. (2013). International Institute for Sustainable Development (IISD) | Ecosystem management emphasized on practical implementation processes | · place-based assessment of the WEF security system<br>· participatory scenarios exercise to envisioning future landscape scenarios<br>· an implementation strategy to invest in the desired future landscape<br>· adoption of a spatially explicit framework for monitoring, and adaptively managing investment performance |
| Walking the Nexus Talk: Assessing the Water-Energy-Food Nexus<br><br>Food and Agriculture Organization (FAO) (2014) | Focus on resource base on both biophysical and socio-economic resources | · data collection to identify inter-linkages and seek evidence<br>· scenario development to highlight possible interventions and policy interventions<br>· stakeholder engagement in open and participatory policy dialogue<br>· select policy response options relevant to national and local nexus-related goals |

these three frameworks and proposed an ecosystem services-oriented framework aimed at supporting decision-making on landscape investment and risk management (Bizikova et al., 2013). This approach is then followed by FAO whereby the concept of WEF nexus is elucidated to explicitly address interactions and feedbacks between human and natural systems in 2014. These five different approaches and frameworks are summarised in Table 2.2.

### 2.2.2 Assessment Tools

Apart from the variety of conceptual frameworks, a widespread of assessment tools to address the water, energy and food security nexus exists that focuses on the analysis of input-output relationships. Since the inception of Bonn 2011 Conference, SEI has attempted to link its important water and energy/ mitigation planning software systems. The Long-range Energy Alternatives Planning system (LEAP) and Water Evaluation and Planning system (WEAP) used together can now represent evolving conditions in water and energy systems, allowing planners to see the implications for each of a wide range of scenarios and policy choices. This combined LEAP and WEAP analytical tool are then integrated with AEZ (Agro-Ecological Zoning by IIASA and FAO) models as well as climate change scenarios (Howells et al., 2013) under the climate land-use, energy, and water strategies (CLEWs) framework.

A Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM) developed by FAO is applied to effectively analyze the nexus between energy, food, and water, taking into account various factors such as population dynamics, greenhouse gas (GHG) emissions and land-use changes at the national or sub-national level. This assessment tool can be employed for diagnostic as well as for simulation purposes (FAO, 2013). The European Innovation Partnership (EIP) has launched an initiative called the W4EF aimed at developing a framework for evaluation and reporting of energy impacts on water. This framework will be based on the development of a series of indicators that can help energy managers make a more efficient use of water resources (EIP, 2013). Meanwhile, the World Bank is spearheading Thirsty Energy Initiative, which is aimed to develop an energy–water modeling framework that incorporates water resources into existing energy modeling to achieve integrated energy-water management (World Bank, 2014)). The Food and Agriculture Organization of the United Nations (FAO) has further emphasised the links to food in its proposal of a WEF nexus framework that includes several components related to food security (FAO, 2014).

Some examples of scenario generation tools designed for the WEF Nexus application are the Foreseer Tool developed by the University of Cambridge and the Water-Energy-Food Nexus Tool by Qatar Environment and Energy Research Institute (QEERI). The former is an online tool for visualising the influence of future demand scenarios on requirements for energy, water and land resources (Curmi et al., 2013). The latter calculates a sustainability index for a proposed scenario, based on resource requirements (water, land, energy, finances, carbon) and relevance factors for each resource type defined by stakeholders (Daher and Mohtar 2015).

All in all, it should be emphasised that WEF nexus approaches and assessment frameworks cannot be understood in isolation, but as a complement to individual water, energy and food management approaches (see Figure 2.2). These frameworks capture the system thinking process and serve as incremental efforts to strengthen coordination, harmonisation, and guidance by deconstructing and highlighting interconnections among the three resources. All knowledge, experiences and successful examples achieved cannot be consigned to oblivion.

## 2.3 WEF NEXUS CONFLICTS IN PRACTICE

Despite the recent emergence of the WEF nexus concepts and frameworks, there are still few examples of results on a practical level. Adoption and implementation of WEF nexus approach may be hampered given that the idea is perceived ambiguous. On the contrary, it can also be argued that the ambiguity of the concept can be capitalised to allow flexibility in the complex set of multiple

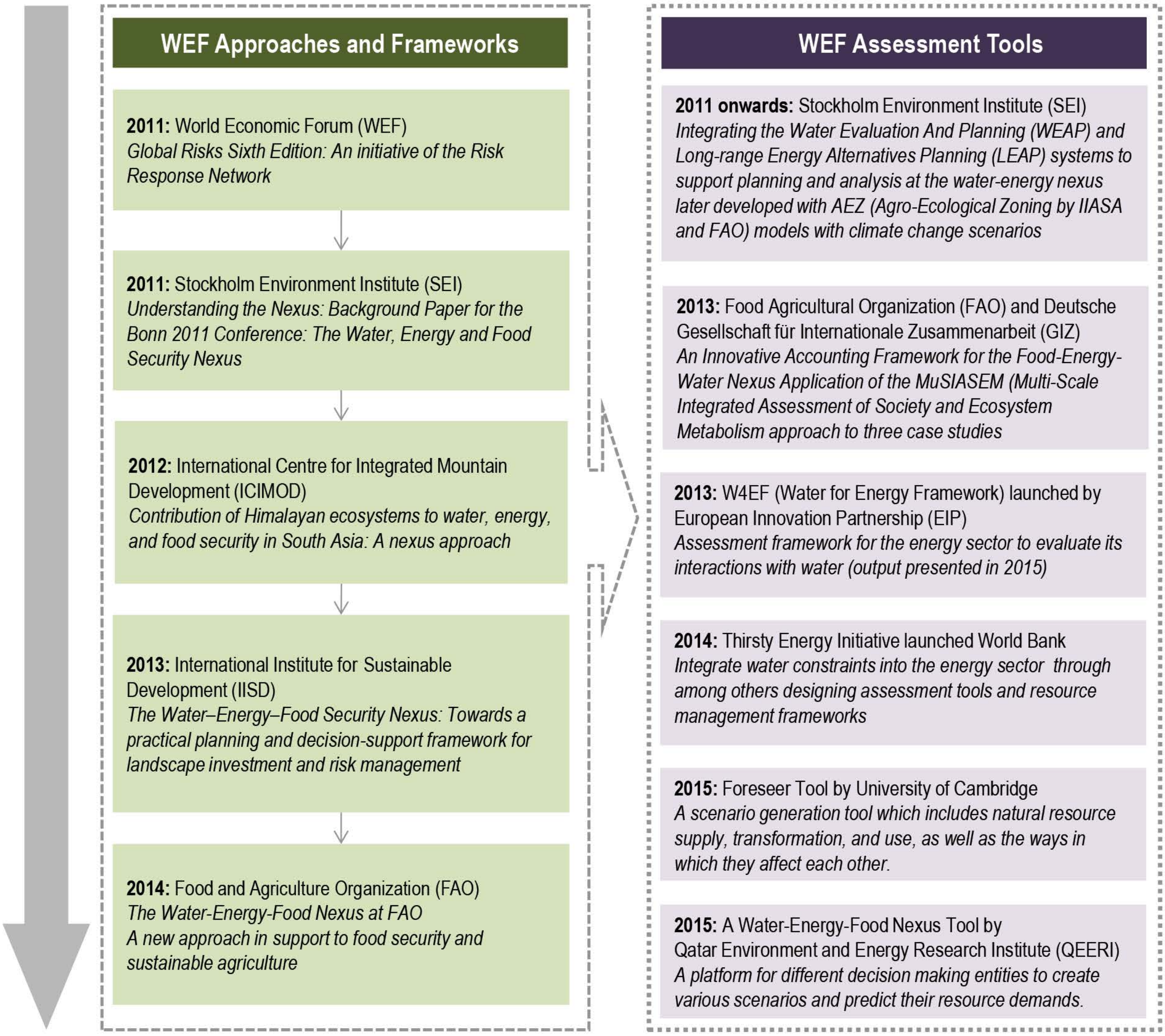



**Figure 2.2: Overview of WEF Approaches, Frameworks and Assessment Tools**

sectors and actors on multiple levels. Such flexible operationalisation and evolution of new conceptual frameworks are necessary along with the rapid development to accommodate complex and dynamic relationships among systems (Meza et al., 2015).

Depending on boundary object and scope, the practical experiences reflected in case studies of both developing and developed countries points to the solution or response options use in policy formulation should be tempered with caution (Jobbins et al., 2015). While these case studies offer examples of challenges and opportunities for managing, governing and applying the WEF nexus, it should be emphasised that they are context-specific in the instances of climate and geographical characteristics, production systems, social capital, governance system and cultures and thus not directly transferable or scalable.

Some of the recent case studies that were introduced in both developing and developing countries to demonstrate the various applications of WEF Nexus frameworks and assessment tools are discussed as the following.

**Table 2.3: Summary of Literature on the Practical Implementation of WEF Nexus Approaches in Developing Countries**

| | Author(s) | Year | Type of Nexus (W-E-F) | Issues and Challenges* | Solutions or Response Options |
|---|---|---|---|---|---|
| 1 | Jobbins et al. (Morocco) | 2015 | W | · Water and energy scarcity<br>· Intense droughts<br>· Depleted aquifers due to intense groundwater pumping<br>· Complex challenges linked to issues of social development, poverty alleviation, institutional reform and international trade | · Drip irrigation as a technical solution with subsidy of 80 percent rising to 100 percent for farms smaller than 5 ha<br>· Institutional reforms<br>· Community-based schemes<br>· Empowerment of private companies to provide technical assistance alongside infrastructure sales<br>· Public-private partnership in irrigation |
| 2 | Keskinen et al. (Tonle Sap and Mekong River Basin) | 2015 | WEF | · Changing flood regime and increased dry season<br>· Shifts in floodplain habitats<br>· Destruction of the flooded forests surrounding the lake<br>· Hydrological and environmental changes affect fish production<br>· Demographic and socio-economic changes | · Define the linkages between the nexus themes through hydrology and water resources and livelihoods and food security analysis<br>· Develop four alternative futures for the Tonle Sap through scenario formulation process with stakeholder participatory approach |
| 3 | Meza et al. (Chile) | 2014 | W | · Extreme climatic regime lead to water scarcity | · Full integration of water and sustainable energy<br>· Comprehensive watershed models able explicitly to take into account energy and water fluxes as well as irrigation practices<br>· Coordination of stakeholders and water users<br>· Implement quantitative model |
| 4 | Golam et al. 2014 (Hindu Kush Region) | 2014 | WEF | · High degree of dependency of downstream communities on upstream ecosystem services<br>· Increasing population and declining agricultural land<br>· Stagnating or declining food production<br>· Increasing water and energy-intensive food production<br>· Water and energy scarcity<br>· Impacts of burning biomass for energy | · Cross-sectoral integration to improve the resource-use efficiency and productivity of the three sectors<br>· Regional integration between upstream and downstream areas is critical to food, water, and energy security<br>· Strengthen management of ecosystems–especially the watersheds, catchments, and headwaters of river systems<br>· Develop appropriate incentives such as payments for ecosystem services and mechanisms for sharing the benefits and costs |
| 5 | Gu et al. (China) | 2014 | WE | · National energy policies fail to address water use issues<br>· Water policies do not consider the impact of energy consumption and GHG | · Characterise coefficient of supply-consumption relationship between the water supply and primary energy sectors<br>· Calculate water-saving effects associated with the enforcement of energy-saving policies in selected industrial sectors |

| | | | | | |
|---|---|---|---|---|---|
| 6 | Gulati et al. (South Africa) | 2013 | F | · Affordability and availability of food have become a growing national concern<br>· High input costs of as a result of water and energy prices<br>· Limited arable land<br>· Difficulty in scaling up of green economy vertically | · Constructing a governance framework for the WEF nexus<br>· Integration of irrigation and nutrient (especially nitrogen) inputs through appropriate irrigation and nitrogen management tools<br>· Couple biogas use (for energy and liquid fertilizer) with rainwater harvesting<br>· Energy savings in the water supply sector<br>· Virtual water trade at the regional level |
| 7 | Granit et al. (Central Asia and the Aral Sea Basin) | 2012 | W | · Political challenges of forming a nation-state since the break-up of the Soviet Union<br>· Transitioning from a centralised to a market-based economy | · Investment in hydropower power generation, regional power market development,<br>· Irrigation reforms, and<br>· Addressing regional environmental public goods such as water flows and quality |
| 8 | Lele et al. (China and India) | 2012 | WEF | · Lack of strategic clarity;<br>· Unequal distribution of power;<br>· Lack of capability in governance<br>· Access to information | · It calls for good governance at all levels including, notably, an understanding of the roles of and linkages between policies and institutions at various political and administrative levels. |
| 9 | Laldjebaev (Tajikistan) | 2012 | WE | · Energy scarcity<br>· Failure of the Soviet mechanism led to inequitable sharing of the region's natural resources | · Construction of hydropower station<br>· Construction of small-scale hydropower station<br>· Improve efficiencies |
| 10 | Siddiqi & Anadon (The Middle East and North Africa Region) | 2011 | WE | · Water scarcity<br>· High population growth and improvements in living standards leads to increasing energy demand | · Country-level quantitative assessment of energy-water nexus in the Middle East and North Africa (MENA) region<br>· Energy implications on virtual water<br>· Rethinking demand to keep flexibility for the future<br>· Rethinking supply |
| 11 | Malik (India) | 2002 | WE | · Shortages/uncertainties/ unreliability in the availability of water and energy<br>· Disconnect between the demand and supply of water and energy | · Expansion of the resource availability<br>· More efficient utilization of the available resources.<br>· Policy and regulatory support;<br>· Institutional arrangements;<br>· Financing |

### 2.3.1 Developing World

A number of case studies on WEF nexus have seen on the rise primarily from the developing country perspective along with progress made in the development of WEF nexus approaches and assessment tool. Partly, this could be because developing countries are more vulnerable to adverse impacts of climate change and other associated global environmental changes (IPCC, 2007). A summary of case studies as illustrated in Table 2.3 presents both challenges and policy responses or solutions in the endeavour to identify trade-offs and synergies in the nexus and thus assist better decision-making and management of the WEF nexus resources.

In a case study of Morocco, Jobbins and colleagues (2015) cautioned that technical options that appear beneficial at the conceptual level in addressing water and energy security could have unintended consequences in practice. Given the complex institutional barriers, policies focused on issues of scarcity and efficiency may exacerbate other dimensions of poverty and inequality.

Keskinen and colleagues (2015) on the other hand confirmed the close synergies of WEF security both in the Tonle Sap and in the trans-boundary Mekong River Basin. It appears that the current drive for large-scale hydropower threatens water and food security at both local and national scales.

The findings of Gu and colleagues (2014) during the implementation of energy saving policies during the Eleventh Five-Year Plan (FYP) from 2005 to 2010 in China suggest that energy-saving efforts will result in savings in water consumption. This positive feedback indicates that cooperative relationship between water and energy conservation efforts should be a major factor in creating policies that encourage simultaneous savings of both resources.

In South Africa, Gulati and colleagues (2013) examined the level of interconnectedness between the WEF systems and the effects of energy and water costs to food prices and its implications for the country's food security. The findings highlight the significant role of energy and water systems in determining the availability, quality, and affordability of food prices and vice versa. This relationship has negative impacts on food security as an increase in food prices will put pressure on consumers.

In the case of Central Asia, Granit and colleagues (2012) underlined the need for collaborative management and development of the trans-boundary water resources in the region is important to meet future water, energy, food, and environmental security needs. Moreover, the program of such is to be within the framework of an appropriate regional institution in which there is political trust.

Siddiqi and Anadon (2011) conducted a country-level quantitative assessment of energy-water nexus in the Middle East and North Africa (MENA) region. The findings interestingly show a relatively weak dependence of energy systems on fresh water but a high dependence of water abstraction and production systems on energy.

### 2.3.2 Developed World

While issues of WEF nexus in the developed countries manifest differently in comparison to developing countries, the consideration of complex interactions that require new institutional capacity is valid both in industrialised and developing countries (see table 2.4).

Mayor and colleagues (2015) developed a 3-step WEF Nexus framework to support decision-making at a regional or context-specific scale based on the two pillars of the WEF nexus concept that are understanding and coordination. This WEF assessment framework is applied for the Duero basin in Spain to detect the most significant conflicts derived from water, food and energy interdependencies.

Halbe and colleagues (2015) presented a methodological framework to analyse sustainability innovations in the WFE nexus and strategies for governing transition processes towards implementation in Cyprus. The application of the integrated assessment model shows the importance of sustainability innovations, which include social innovations (e.g., conscious consumption) and technical innovations (e.g., renewable energy) and also the need for a reflexive governance approach to induce a sustainability transition.

Walker and colleagues (2013) explored the urban metabolism of London by identifying interactions among the fluxes of five resources (C, N, P, water, and energy) that are circulating around five economic sectors (water, energy, waste-handling, food, and forestry) using the Multi-sectoral Systems Analysis (MSA). Results show that the selection of the best technological innovation depends on which resource is the focus for improvement.

Drawing on case studies from Australia, Europe, and the United States, Hussey and Pittock (2012) contributed to the WEF Nexus discourse by introducing "The First Four Steps to Achieving Sustainable Energy and Water Security", a collection of critical questions for policymakers at the local, regional, and state levels that will allow them to unpack the energy-water nexus in their jurisdiction and, consequently, begin to manage it.

Findings of Scott and colleagues (2011) in exploring WEF Nexus in the United States reveal that localised challenges are diminished when considered from broader perspectives, while regionally significant problems are not prioritised locally. The transportability of electricity, and to some extent raw coal and gas, make energy more suitable than water to regionalised global-change adaptation because many of the impacts to water availability and quality remain localised. We conclude by highlighting the need for improved coordination between water and energy policy.

## 2.4 WEF NEXUS SOLUTIONS

The novelty of the W-E-F nexus approach is determined by its complexity to deal with a plurality of policies at different levels that are underscored by new coordination mechanisms within and between institutions and disciplines as well as new forms and types of capacities to be effective. The precursor of nexus governance is a need for evidence-based research and for the development of conceptual governance frameworks as showcased in various case studies. However, use of WEF nexus solutions and policy responses in policy formulation as illustrated should be tempered with caution since achieving desired outcomes might be highly specific. The development and prescription of WEF nexus solutions require innovative policy strategies coupled with appropriate technological infrastructure. Turning double-edged sword into win-win solution calls for system thinking approaches used in an integrative manner to mediate trade-offs and explore synergies towards human well-being and healthy ecosystems.

Water is by far the most complex of natural resources to manage compared to energy and food. Arguably, it has no boundaries and therefore is not amenable to political or administrative restrictions. Nor is it amenable to a simple instrument, such as centralised or decentralized governance and markets vs. states (Lele et al., 2012). Crucially, operationalising WEF nexus approaches and assessments require significant financial and human resources. Also, it enhances decision-making and management of the WEF nexus resources which eventually lead to economic benefits. Both the forces of supply-push and demand-pull policy responses are interdependent in the emergence of WEF nexus. In this view, a functional ecosystem requires demand-led technological and market solutions that are implemented in balance with the supply-side limits and governance solutions regarding management over and access to resources.

### 2.4.1 Technological Solutions

Development of technologies to build WEF infrastructure and promotion of technologies is often framed as solutions via economic incentive to exploit the potential for more efficient, cost-effective system. The case studies of drip irrigation adoption in Morocco depicts the common misconception that technology fix automatically offers water and energy efficiency savings while maintaining, or even increasing, agricultural production and productivity. This example reflects the local realities and issues that are attributed to poverty and marginalisation rather than efficient energy usage. It is important that supporting policies are carefully targeted to ensure potential distributional impacts, and that the technical, institutional and policy options proposed are supportive of pro-poor agendas of inclusive social and economic development.

**Table 2.4: Summary of Literature on the Practical Implementation of WEF Nexus Approaches in Developed Countries**

| | Author(s) | Year | Type of Nexus (WEF) | Issues and Challenges | Solutions or Response Options |
|---|---|---|---|---|---|
| 1 | Mayor et al. (Spain) | 2015 | WE | · Rising energy prices for irrigated agriculture due to modernisation<br>· Limitations to water treatment<br>· Possible emergence of new water demands for energy by<br>· hydraulic fracturing for oil and gas<br>· Enhanced bioenergy | · Creation of groundwater users' associations for the development of strategies to reduce or share pumping energy costs and look for alternative solutions to acquire irrigation water.<br>· 'Schools for mayors', where mayors from different villages are invited to thematic workshops where they are informed about relevant water ecosystems' sustainability issues and concerns<br>· Review and revise of all hydropower concessions in the basin to ensure their compliance with the legislation<br>· Inclusive energy planning stakeholders to air existing problems and conflicts derived from nexus trade-offs to be considered by energy planners, who may not be able to detect them from a strategic energy-oriented position.<br>· Evaluation of the 'energy footprint' of irrigation modernization and additional examination of energy trade-offs on water availability needs to be included |
| 2 | Halbe et al. (Cyprus) | 2015 | WEF | · Role of stakeholders in solving sustainability issues and their role in defining sustainability problems<br>· The terminology of reflexive governance approach is often too unspecific and abstract<br>· Monitoring and evaluation of sustainability of solutions | · Methodological framework for the governance of transitions in the WEF nexus<br>· Causal loop diagrams (CLD) as systems thinking approach for the depiction and qualitative analysis of systems<br>· Explore responsibilities of different stakeholders systematically for the implementation of innovations and thereby provides critical information for reflexive governance processes<br>· Breaking down complex system interactions into a simple set of actions is likely to facilitate the engagement of stakeholders. |
| 3 | Walker et al. (Greater London) | 2013 | WEF | · The effect of human behaviour on the metabolism of the city from the flows of material from surrounding hinterland to the city | · Urine separation can potentially recover 47 percent of the nitrogen in the food consumed in London, with revenue of $33 M per annum from fertilizer production<br>· Collecting food waste in sewers together with growing algae in wastewater treatment plants could beneficially increase the amount of carbon release from renewable energy by 66 percent, with potential annual revenues of $58 M from fuel production. |

| | | | | | |
|---|---|---|---|---|---|
| 4 | Hussey and Pittock (Australia, Europe, and the United States) | 2012 | WE | · Fragmentation between legislation and/or poor implementation of legislation;<br>· Inadequate resources and/or training to undertake key processes<br>· Lack of integration between the major agencies and sectors in the planning phase;<br>· Lack of on-going review and evaluation mechanisms to identify problems.<br>· Missing unconsolidated, conflicting, and uncertainty in data; or access to industrial data<br>· Water and energy sectors have always operated independently, and there is a (natural) resistance to integrate the two better<br>· Attitude that engineering/ technical solutions are optimal remains dominant at the expense of more holistic solutions | · Undertake international comparative studies to identify better-practice initiatives that can be disseminated across the public policy, energy, and water communities |
| 5 | Scott et al. (United States) | 2011 | WE | · Governance mismatch between global drivers and local resources | · Importance of multi-tiered institutional arrangements and resource governance – laws, policies and organizations that operate across jurisdictional<br>· Water–energy nexus construct considers institutions not just resource inputs<br>· Energy policy offers more scope for global-change adaptation than does water policy |
| 6 | Gold and Bass (United States) | 2010 | WE | · Energy and water shortages<br>· High transaction cost in implementing renewable energy projects<br>· Policy Inconsistency among the state's actors | · Statutory definitions of "public interest" should be amended to include socioeconomic concerns<br>· Jurisdiction over siting processes should be expanded to include smaller projects<br>· Energy project and water transfer approval processes should provide for compensation for socioeconomic impacts<br>· Statutory definitions of "beneficial use" should be broadened to include low-water-use renewable energy production<br>· The legislative changes suggested in this article are pursued |

**Note: * Both internal (input-output between resources) and external linkages (investments, migration, trade)**

The potential of natural or green infrastructure in addressing WEF security challenges often falls short of its potential. Ozment and colleagues (2015) argued that "integrating natural infrastructure with engineered solutions provides a promising approach that can help to reduce costs, protect and restore ecosystem services, enhance resilience to climate change, and provide a suite of additional social and economic benefits." Natural infrastructure can either be implemented based on its capacity to complement, augment or as a substitute to the services provided by traditional engineered or gray infrastructure.

However, natural infrastructure solutions are often inadequately considered as a policy option due to its complexity and presence of information gap in the system design that requires a longer time horizon. Arguably, the lack of clarity on its interactions with the regulatory systems has also deterred its attractiveness to investors. As such, availability and access to quality data is another area necessitate for WEF assessment. Systematic monitoring and evaluation of policy interventions demand new information technology which will be critical in increasing efficiency and connectivity.

### 2.4.2 Governance Solutions

Governance challenges are at the core of the nexus in many areas. Governance issues are entrenched in policy, institutional, technological and financing options exercised at the global, regional, national and local levels (Lele et al., 2012). Often there are huge trade-offs between the short-term wins of individual stakeholders and long-term holistic solutions. The application of nexus governance at the global, national, regional and local levels requires a different set of policies and institutions and outcomes for addressing these complex challenges. Noteworthily, each level of policy-making should take impacts at the local level into consideration the emphasis of knowledge sharing between users and policymakers.

Recently, Villamayor-Tomas and colleagues (2015) emphasised that nexus approaches are yet to actively engage with the institutions that mediate environmental outcomes, proposing that the combination of an Institutional Analysis and Development framework with a value chain analysis could contribute towards filling governance gap (Ostrom, 1994). Arguably, as existing nexus frameworks are process-based approaches to resource use, and show a preference for systems analysis and modeling over other empirical strategies, these frameworks on systems approaches do not necessarily reflect the institutional realities as it is the private-sector supply chains, which largely determine energy and climate-change policies.

Finally, holistic WEF nexus solutions should not be restricted to the political and institutional levels. WEF management is also required at business and societal levels to build resilience and agility at all scales. A reflexive governance approach as argued in Halbe and colleagues (2015) entails learning processes in the individual, group, organisational and policy contexts to implement sustainability innovations through coordinated action.

# 3 NATIONAL WATER-ENERGY-FOOD SECURITY

## 3.1 BACKGROUND

Among all natural resources, water is the most crucial means to development with about 90 percent of economic activities are dependent on it. In a sense, all the benefits that humanity gets from natural resources are (becoming) secondary to water use. Next to water, energy is essential natural resources for development which sustains societies, economies, and ecosystems. Similarly, energy and food have always been of high strategic significance to society and to the governments that are responsible for their security. As water resources become more scarce and uncertain because of the population, climate change, and wastage, the efficient use of water with energy and food production becomes more urgent.

Malaysia's foundation for development was its resource-based economy (Vincent and Ali 1997), unlike the so-called East Asian tigers such as South Korea, Taiwan, Hong Kong and Singapore. Peninsular Malaysia has attracted foreign powers for centuries due to its nonfuel wealth, mainly tin. By the end of the 19th century, Malayan tin accounted for over 40 percent of total world production. Similarly, the basis of the country's economy during the formation of the Federation of Malaysia in 1963 was in utilising mineral and land resources. Be that as it may, many consider Malaysia an example of where the resource curse did not strike (Sachs and Warner 1995), as rapid development allowed for Malaysia to chart impressive growth rates since its formation. Figure 3.1 illustrates the country's material flow from 1970 to 2008, indicating that consumption and production patterns of natural resources and minerals have been increasing steadily throughout the years.

Malaysia's increase in GDP per capita, the standard of living, and voracious overall consumption is expected to lead to an unsustainable pressure on natural resources, especially water, energy, and food. The subsequent sections provide a cursory assessment of the status and individual challenges of water, food and energy security in Malaysia at the national level. The dimensions deemed important for resource security assessment in Malaysia include availability, accessibility, efficiency, stability, utilisation and sustainability. The concluding section discusses Malaysia's current policy responses in confronting the security dimensions of the three strategic resources.

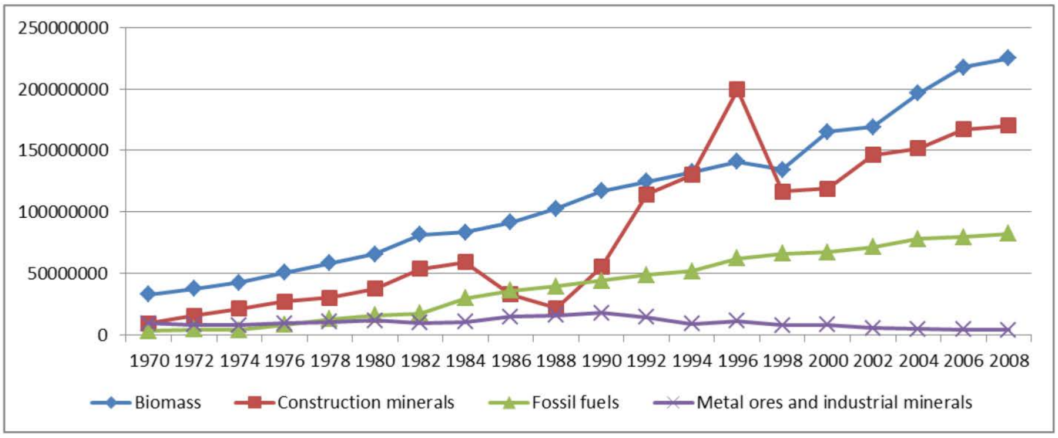



**Figure 3.1: Total Domestic Material Consumption in the World, Malaysia, 1970–2008**

**Source: CSIRO and UNEP Online Asia-Pacific Material Flows Database, as of September 2012. Available from www.cse.csiro.au/forms/form-mf-start.aspxClimate Mitigation**

## 3.2 WATER SECURITY

The UN-Water Task Force on Water defines water security as "...the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability". The following five security parameters of availability, accessibility, affordability, efficiency and sustainability are essential in discussing water resources security in Malaysia.

### 3.2.1 Availability

Malaysia is relatively well endowed with water resources when compared to the size of its population. Water availability is good because Malaysia receives about 3.5 times more rainfall than global annual average with 2,940 mm a year. Its 189 major river systems provide potable water supply, a source of food in fisheries, irrigation for agriculture, hydroelectric power, serves as a means of transportation, and supply water use for industries. They are also rich ecosystems supporting a rich biodiversity of flora and fauna.

Malaysia's water availability is therefore considered good for sustaining livelihoods, human well-being and socio-economic development. With renewable internal freshwater resources amounting to 20,098 cubic meters per capita, the World Bank data (2010) puts Malaysia at 34$^{th}$ out of 176 countries concerning availability water freshwater resources.

However, the water availability situation for some parts of the country has changed from one of relative abundance to one of scarcity. The 2010 National Water Resources Study has identified Perlis, Kedah, Penang, Selangor and Malacca as water-deficit states. Rapid urbanisation and Malaysia's transformation from an agrarian to industry economy since the 1980s has led to increasing demand for water resources which was further beset by rivers suffering from polluting activities. Malaysia's water requirements will increase by 63 percent between 2008 and 2050, from 11 billion to 17.7 billion cubic metres (EPU, 2000). There is concern over water quantity decreasing due to climate change. What actually triggered 'a sense of crisis' of Malaysia's water resources availability was the increasing frequency of interruption in water supply in the 1990s (Aini et al., 2001), a predicament which is continuing until today.

### 3.2.2 Accessibility

Malaysians enjoy a high level of connectivity to treated water. The World Bank regards access to water and sanitation in Malaysia as above regional and world averages. In 2012, 94.7 and 94.5 percent of the population had access to piped water and sanitation respectively (Yen and Rohasliney 2013). As of 2014, 95.1 percent of the Malaysian population have access to clean and treated water, up from 90.5 percent in 2007 (Malaysia 2015). But this access varies between urban and rural areas (Figure 3.2 ) for different consumption per capita between urban and rural states). Except for Kelantan with 59.5 percent access, most states recorded more than 99 percent coverage in urban areas. Rural coverage for Kelantan, Sabah and Sarawak remained below 80 percent, hence needs to be further improved especially in the villages of indigenous groups, small estates and rural schools in remote and difficult-to-access areas.

### 3.2.3 Affordability

Malaysia also scores well on water affordability for consumers as it sustains one of the lowest water tariffs in the world (Figure 3.3). Nonetheless, with under-priced water resource, some Malaysians continue to consume more than many of their peers. In 2014, urban dwellers in the state of Penang, for instance, consumed as much as 293 litres per capita per day (Figure 3.2) (Malaysian Water Association 2015). Consumers in Kelantan use only 147 litres per capita per day due to the availability of groundwater as an alternative source of water supply.

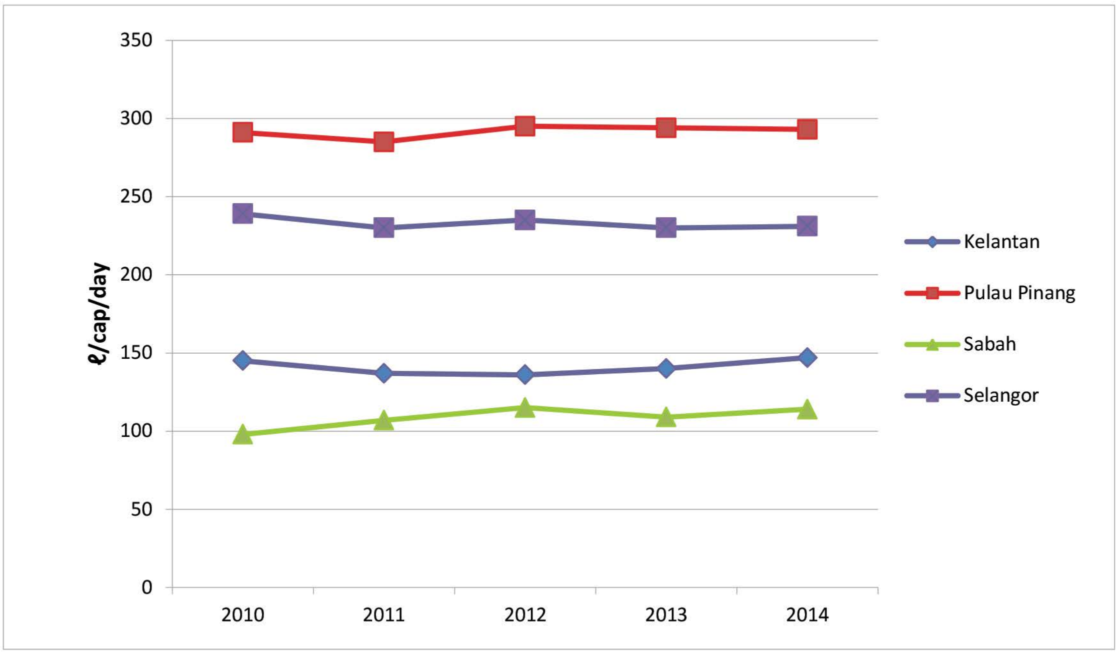



**Figure 3.2: Domestic Water Consumption Per Capita Per Day, 2010 – 2014**

**Source: Malaysia Water Industry Guide, 2015**

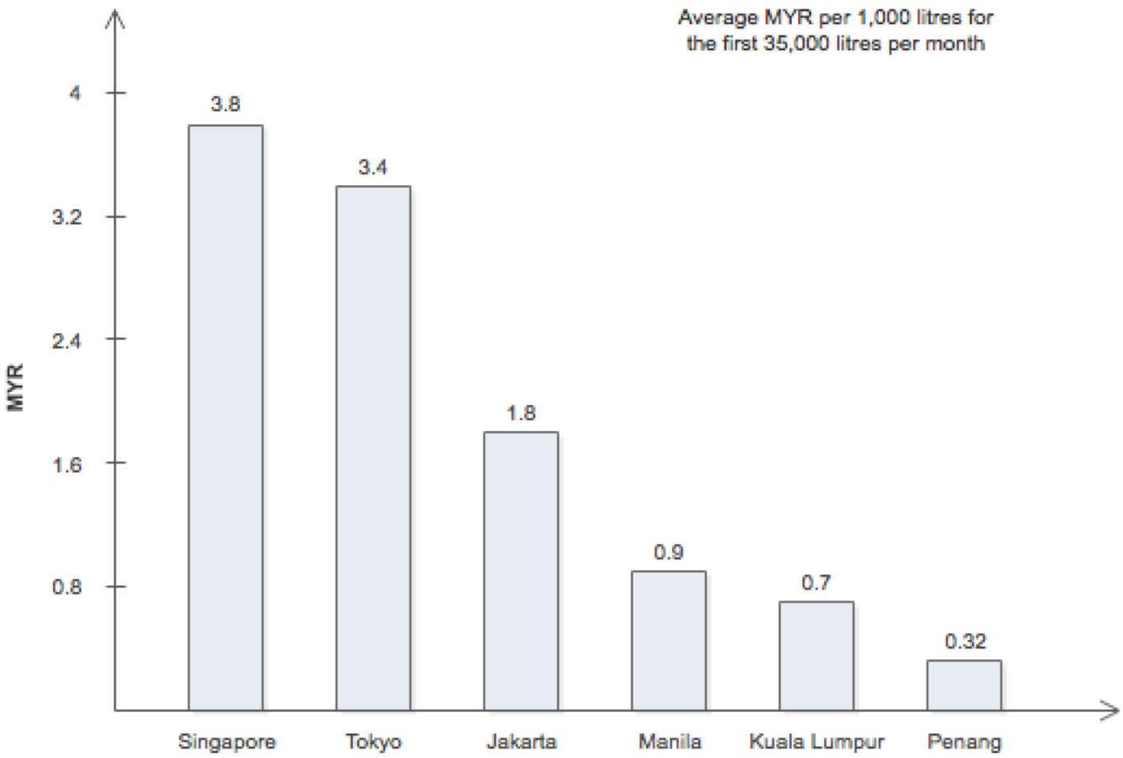



**Figure 3.3: Average water prices of cities in Asia**

**Source: PBAPP, 2014.**

### 3.2.4 Efficiency

Another water insecurity challenge Malaysia faces is the operational efficiency of its water supply systems. The country suffers from old water infrastructure causing a high unaccounted-for water loss or Non-Revenue Water (NRW), ranging from 38 to over 50 percent in many states. This loss has hurt the states' fiscal positions. Malaysia's NRW average rate is 36.6 percent in 2013 (Malaysia 2015) where the World Bank recommends NRW not to exceed 25 percent. NRW rate was highest in Perlis at 62.4 percent and Sabah at 53.2 percent. Operational efficiency is especially crucial since the small water charges covered only 78 percent of the operating expenditure (Ching 2012).

The problem of water management calls for a shift from only focusing on supply to demand-side management (Falkenmark and Lindh, 1993). During the Eleventh Plan, NRW will be reduced from 36.6 percent in 2013 to 25 percent with the implementation of a holistic NRW reduction programme. This plan includes the development of a comprehensive district metering zones, incorporating meter and pipe replacement programmes, and pressure control management. *Ceteris paribus*, with lower demand as a result of NRW reduction, there will be less pressure on water resources in the future.

### 3.2.5 Sustainability

The greatest water security challenge has to do with ensuring protection against water-borne pollution. It is pertinent to note that the abundant water resources available in the country do not guarantee adequate supply to all users because of river pollution and water catchment degradation. Figure 3.4 illustrates the impact of river pollution on the operation of water treatment plant managed by Puncak Niaga Sdn Bhd in the State of Selangor. River pollution reduces total water availability considerably, and in some instances, polluted waters are not treatable for consumption. Mohd. Akbar and Rusnah (2004, p.7) list six water treatment plants in Malaysia that were "forced ... to be abandoned at a substantial loss," and another five that "had to be upgraded technically incurring huge costs in order to maintain their utility," due to degradation of source water quality caused by "extensive logging and land clearing." Climate change is exacerbating the problem by decreasing the safe yield of rivers which in turn resulting in water treatment plants not being able to produce to their design production. In some cases, adaptation measures may require relocating river intake further downstream where yield is higher or constructing a barrage/weir across the river to increase water depth. Water quality is

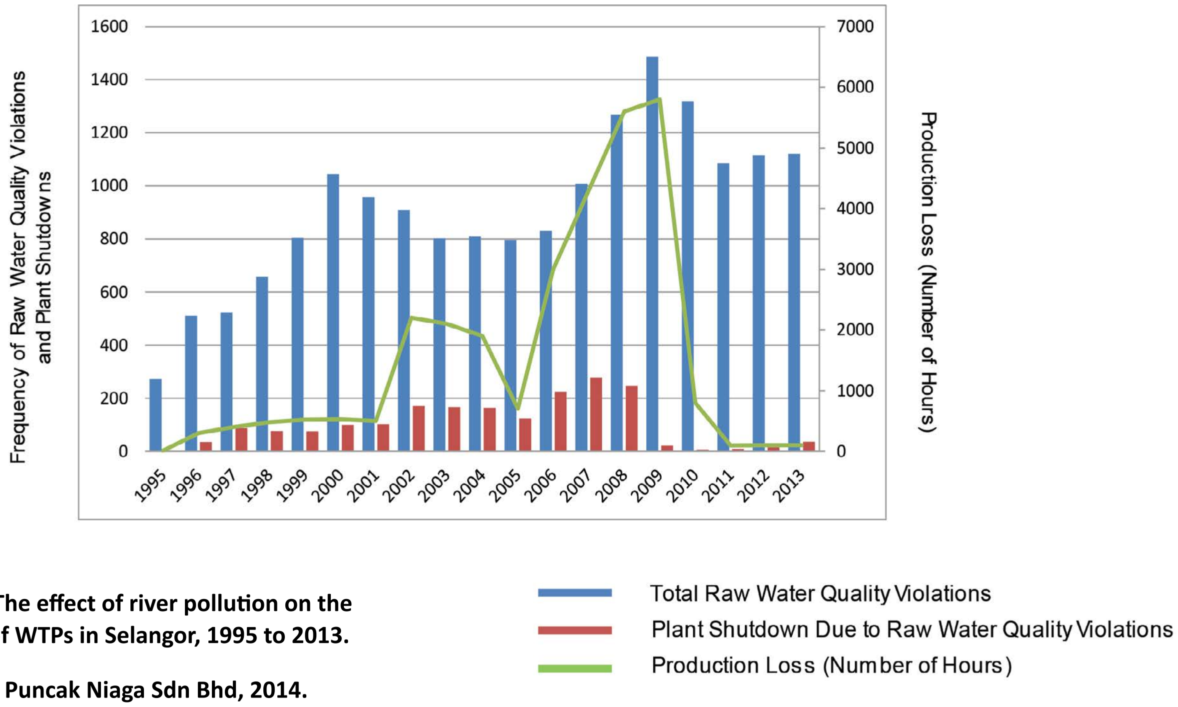



**Figure 3.4: The effect of river pollution on the operation of WTPs in Selangor, 1995 to 2013.**

**Source: Puncak Niaga Sdn Bhd, 2014.**

degrading due to environmental destruction within water catchment areas, deforestation, and pollution from the industry since the 'roaring 1990s'. As a result, consumers are increasingly concerned with the quality of piped water mainly turbidity and unpleasant odour (Othman et al. 2014). Consumer perception is reflected in households resorting to water filtration systems installation – 5 percent in 2012 and expected to rise to 7 percent in 2016.

## 3.3 ENERGY SECURITY

Energy security parameters include its availability, stability, affordability, efficiency, and sustainability. In an index of energy security developed by Sharifuddin (2013), Malaysia performs better than its ASEAN neighbours Indonesia, Thailand, Vietnam and the Philippines from 2002 to 2008 on most parameters. However many challenges remain. The major energy security challenges of Malaysia presently take the forms of a voracious domestic demand and a depleting domestic resource base. Malaysia's energy security could deteriorate when it becomes a net energy importer. Not only will Malaysia's energy supply become exposed to geopolitical and global market risks, but dwindling energy export profits threatens to unwind its energy subsidy 'system,' thus directly exposing the population to the risks of price increases and volatility.

### 3.3.1 Availability

For many years Malaysia was a net energy exporter rendering energy availability as a marginal security concern. The energy sector, particularly oil and gas exports, has supported its economic growth for the past two decades. The increase in domestic production of oil and gas has allowed the population to enjoy a healthy increase in energy consumption, with primary energy supply per capita increasing 128 percent between 1990 and 2008. As a net exporter of oil and gas, Malaysia has gained a substantial degree of security concerning guaranteeing the available volume of primary energy, despite being a net importer of coal.

Access to modern energy services is exemplary since Malaysia's electrical power grid system has covered more than 90 percent of the country. In the future, however, Malaysia is likely to suffer from uneven distribution of power with the Peninsula constrained by peak electricity demand. The government has proposed to use of nuclear energy (2 units of 1000 MW) to provide a cleaner, stable and reliable baseload source of energy as compared to coal-and gas-driven generators.

Malaysia's gas production has also allowed the country to diversify its electricity generation fuel-mix away from fuel oil in the 1990's. Further, Malaysia's oil and gas exports have allowed the country to finance the imports of coal which helped to diversify its electricity generation fuel-mix away from away from natural gas. Coal consumption is split roughly 60:40 between industry and other sectors, with consumption in the former as a primary energy form and consumption in the latter in the form of electricity.

This energy security scenario has changed in recent years as Malaysia's own petroleum reserves are depleting. As of 1 Jan 2013, Malaysia has only 5.850 billion barrels of crude oil remaining (5.954 billion barrels in 2012), or no more than 24 years of current production (Energy Commission 2014). It also has 98.320 trillion standard cubic feet (tcsf) of natural gas reserves remaining, equivalent to 38 years of current production. Discovery of gas in Sarawak's Adong Kecil West-1 and Pegaga-1 wells has increased by national reserves by 6.7 percent from the 2012 level of 92.122 tcsf. But even this discovery does negate the fact that Malaysia could become a net oil importer by 2022 and a net energy importer by 2026 (ISIS Malaysia 2014). In 2013, Malaysia's total imports of energy showed an increase with a 13.7 percent growth rate. The share of imports is 55.9 percent oil, 27.3 percent coal and 26.8 percent gas (Energy Commission 2014).

### 3.3.2 Stability

The total electricity generation capacity is higher than the peak demand for the three years under consideration (Energy Commission 2014). This excess

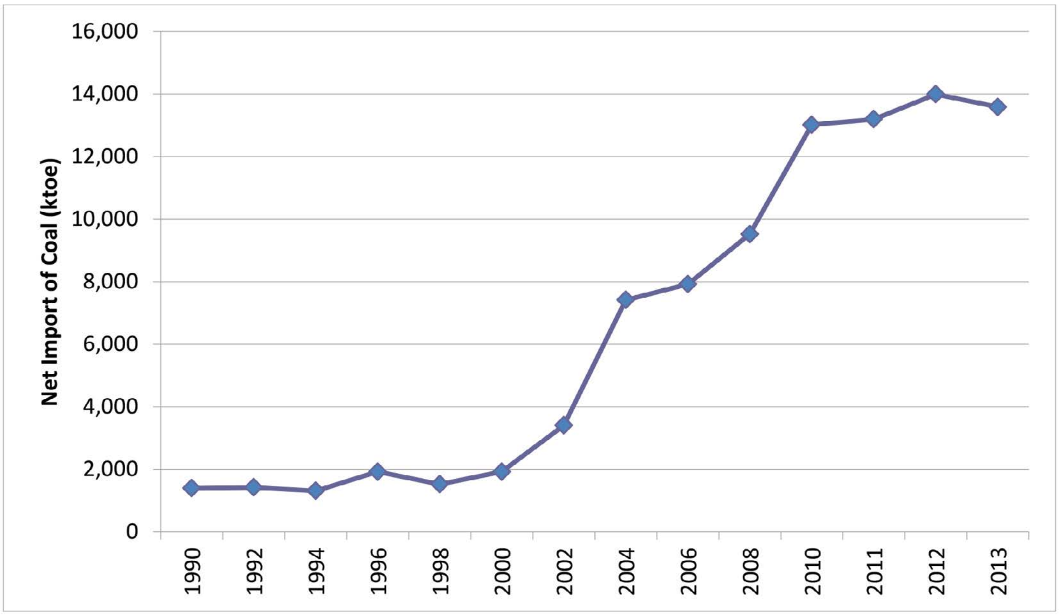



**Figure 3.5: Net Import of Coal, Malaysia, 1990-2013**

**Source: Energy Commission, 2013.**

indicates that there is high reserve margin in the electricity sector. However, supply security for power generation will be a challenge in the future because Malaysia is increasingly dependent on imported coal. Although the Peninsula has a high installed electricity generation capacity, it is increasingly constrained by the availability of fuel. With its natural gas gradually being replaced by coal sources, Malaysia has to purchase coal from producers like Indonesia, Australia, China and South Africa (Figure 3.5). Given that the outlook for global demand for coal exports is uncertain and that its price is not expected to increase substantively, source-diversity may not be a pressing issue for Malaysia's energy security in the near term. However, accessibility may be a challenge in the long term. Although coal is the cheapest and most abundant fossil source, its price and supply are entirely controlled by suppliers. Consistent greater volumes from Indonesia and Australia may not be possible as these countries are consuming more and more of its production.

Malaysia's infrastructure for power generation is very well developed. The total installed generation capacity as at the end of 2013 stood at 29,748MW. The total installed generation capacities in Sabah and Sarawak are 2,196 MW and 3,447 MW respectively, compared to the Peninsula's 24,105MW capacity. Some of the power stations on the east coast of Sabah still showed low levels of reliability due to the use of outdated technologies (Energy Commission 2013). The additional capacity of 600MW from Bakun hydro installation in Sarawak has increased by 2.1 percent nationally from the 2012 level (Energy Commission 2014). National energy security remains a challenge since about 4200 MW from power plants run by the independent power producers (IPPs) will be decommissioned from 2015 to 2020 while nation-wide electricity demand keeps increasing (Cheng and Lalchand 2013). For instance, the generating capacity connected to the grid was reduced by 120 MW with the decommissioning of the Pasir Gudang Power Station Unit 1 in 2013 (Energy Commission 2013).

The country's gross electricity generation in 2013 was 143,497GWh, marking an increase 6.8 percent from 134,375GWh in 2012. Regarding electric power use, the industrial sector is the primary user with the share of 45.4 percent out total consumption of 123,076GWh in 2013. Other sectors consumed less with 32.7 percent commercial, 21.4 percent residential, 0.2 percent transport and 0.3 percent agriculture. Efforts have been undertaken to reduce a high dependence on gas in the fuel mix by turning more to coal due to its lower cost compared to other fossil fuel types. The 2013 share of energy input in power stations is 43.7 percent coal, 43.7 percent natural gas, 8.7 percent hydropower.

### 3.3.3 Affordability

In the past Malaysia was known to spend a huge sum on consumer and producer energy subsidy. Transport fuel, for instance, has been subsidised since 1983 and in 2011 had amounted to almost 11.18 percent of the government's operating expenditure or 2.3 percent of the country's GDP (IISD 2013). In 2012, comparatively, Malaysia had the second lowest price for petrol and diesel in the region (Brunei the lowest). Beginning from 1 December 2014, Malaysia has introduced and implemented the 'managed float mechanism' involving a pricing mechanism that passes price fluctuations through to the consumer using a predetermined formula. This step has marked the government's commitment to cutting down on fuel subsidies.

On the consumer affordability parameter, Malaysians pay less for electricity than neighbours in the region. The low power tariff consequently encourages wastage by consumers with Malaysia recording a higher per capita consumption than Philippines, Thailand, and other middle-income countries. For many years, oil exports have also allowed Malaysia to finance a petrol and diesel subsidy program that results in Malaysian retail prices being close to the bottom 10 percent of the world in 2008. These low prices can be sustained for as long as oil export profits are sufficient to cover the cost of the subsidy. Since 1997 PETRONAS has paid more than RMR160 billion (US$51 billion) to subsidise the power sector in Malaysia, including privately owned power producers, and commercial, residential and transport sectors (Aris, 2012).

Further, natural gas is required to be sold by the producer, PETRONAS, to power utilities at fixed, below-market prices (but above the cost of production). For instance, the domestic sales price of LNG ex-Bintulu for power utilities was about 30 percent of the market price (ISIS Malaysia 2014). PETRONAS can accept these prices because it makes hefty profits from exporting the rest of the domestic production. This situation indirectly means that the benefits from gas exports have allowed the Malaysian population to enjoy a cheap and stable supply of electricity, and they may continue to do so for as long as PETRONAS can make sufficient profits from exporting gas. The current global situation of low oil prices of below US$ 40 per barrel may render this subsidy unsustainable.

### 3.3.4 Efficiency

Although energy efficiency is a low hanging fruit in the quest for energy security, there are many challenges that Malaysia still faces to improve on this. A study on the environmental impact of the Malaysia's Fuel Diversification Strategy showed a negative result of increasing amount of $CO_2$, $SO_2$ and $NO_x$ emissions over the years (Jafar et al. 2008). To achieve environmental sustainability with the proposed fuel mix, greater emphasis must be given to improving the conversion efficiency of energy emissions.

Initiatives that have been undertaken to improve Energy Efficiency (EE) are categorised into three sectors, namely, Industry, Commercial and Residential. For the industry sector, the enforcement of *The Efficient Management of Electrical Energy Regulations 2008* under the *Electricity Supply Act* will ensure that any installation which consumes more than 3 million units (kWh) of electricity over a period of six months will be required to engage an electrical energy manager responsible for efficient utilisation of energy in the installation. As for the commercial sector, the government of Malaysia has taken several pro-active actions in promoting energy efficiency through the construction and operations of several low-energy buildings, such as Low Energy Office (LEO) building of the Ministry of Energy, Green Technology and Water in 2004 and the Green Energy Office (GEO) of Malaysia Green Technology Corporation (MGTC) in 2008.

A green building rating tool called the Green Building Index (GBI) has also been introduced for all types of buildings to encourage the construction of green buildings. The Code of Practice on the Use of Renewable Energy and Energy Efficiency in Non-Residential Buildings under MS 1525:2001 will be incorporated in the amendments to the Uniform Building By-Laws (UBBL) for all buildings in Malaysia. In the residential sector, the EE initiatives include the introduction of 'Star Labeling' in 2002, with five-stars products being the most efficient product and one-star being the least efficient products. Currently, four household appliances have been issued 'star labels,' namely, television, refrigerators, domestic electric fans and air conditioners (split unit).

### 3.3.5 Sustainability

Like most countries, Malaysia is still very much dependent on fossil fuels as a source of energy supply. Oil and gas have maintained a share of over 80 percent of primary energy supply from 1998 to 2007, although this has steadily decreased from 91 percent in 1998 to 83 percent share in 2007. The share of coal in primary energy supply, however, has experienced a slight increase from 3 percent in 1998 to 12 percent in 2007 (IEA 2009; Mat Sahid et al. 2013). The dominance of fossil fuels is apparent in electricity generation whereby 43.7 percent of installed capacity in 2013 was based on coal, another 43.7 percent on natural gas, 8.7 percent on hydro, 2.0 percent on diesel, 1.3 percent on fuel oil, and negligible capacity based on new and renewable energy (NRE) at 0.7 percent. Sustainability is also an increasing challenge since Malaysia's per capita $CO_2$ emissions from fuel combustion had increased by 32 percent from 2000 to 2006. Also, coal usage will likely to increase Malaysia's emissions further.

## 3.4 FOOD SECURITY

Food security is multidimensional, and its meaning evolves with time. At the 1974 World Food Conference, the term 'food security' was defined with an emphasis on supply. The World Food Summit of 1996 defined food security as existing:

> "…when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life."

This definition contains four security dimensions. First is the physical availability of food. Food availability addresses the "supply side" of food security and is determined by the level of food production, stock levels, and net trade. Second is the economic and physical access to food. An adequate supply of food at the national or international level does not in itself guarantee household level food security. Concerns about insufficient food access have resulted in a greater policy focus on incomes, expenditure, markets, and prices in achieving food security objectives. The third dimension involves food utilisation, commonly understood as the way the body makes the most of the various nutrients in the food. Sufficient energy and nutrient intake by individuals is the result of healthy food preparation, feeding practices, diversity of the diet and intra-household distribution of food. Combined with the good biological utilisation of food consumed, this determines the nutritional status of individuals. Finally, the stability of the three dimensions of availability, accessibility, and utilisation over time is another crucial dimension to ensure food security.

### 3.4.1 Availability

Historically, national food self-sufficiency in Malaysia has been equated with food security (Bala et al. 2014). The key indicator used in measuring Malaysia's food production is self-sufficiency level (SSL) mainly for its staple food, rice. After the world cereal crisis in 1973, Malaysia initiated an interventionist strategy to protect the domestic rice sector from the uncertainties of global rice market. The highest SSL was achieved in 1975 with 95 percent of Malaysia's domestic rice requirement was met with home production (Arshad and Hamed 2010). Under the Ninth Malaysia Plan, for example, the country has set a target of 90 percent SSL for rice production by the year 2010 (Table 3.1). This target has involved increasing local rice. Cropping intensity was also increased from an average of 152.5 percent to 159.5 percent (MoAAI 2008). The current target is to achieve full sufficiency level by the year 2020.

**Table 3.1: Food Self-Sufficiency Level, 2000-2020**

| Commodity | 2000 | 2010 | 2015 | 2020 |
|---|---|---|---|---|
| **Crops** | | | | |
| Rice | 70 | 63.1 | 71.4 | 100 |
| Fruits | 94 | 103.3 | 101.6 | 106.5 |
| Vegetables | 95 | 89.8 | 91.8 | 95.1 |
| **Livestock** | | | | |
| Beef | 15 | 30.1 | 27.2 | 50.0 |
| Mutton | 6 | 12.2 | 17.3 | 24.6 |
| Poultry | 113 | 105.6 | 104.6 | 103.7 |
| Pork | 100 | 94.7 | 88.7 | 83.1 |
| Eggs | 116 | 114.6 | 122.1 | 130.0 |
| Milk | 3 | 8.5 | 13 | 13.6 |

**Source: Wong, 2012; Malaysia 2015.**

Malaysia's industrialisation strategies since the 1980s have involved not only the realignment of national policies from agricultural to industrial based but also the conversion of agricultural land and increased imports of food (Mohamed and Damin 2015). Consequently, although Malaysia is at present self-sufficient in palm oil and other commodities, its level of self-sufficiency for sugar, rice, and vegetables as well as beef, mutton, and dairy products is relatively lower (Rahman 1998).

The land use for agriculture in Malaysia is geared to producing commodities for export rather than to fulfill the food requirements of the nation. As of 2005, only 16.3 percent of the land was devoted to food crops such as rice, vegetables, fruits and coconuts (Arshad and Hamed 2010). With an annual growth of 5.9 percent, areas under oil palm in Malaysia increased from 641,791 hectares in 1975 to 5.0 million hectares in 2011 (Malaysian Palm Oil Board, 2013). By 2012, oil palm plantations occupy 15.4 percent or 5.08 million hectares of Malaysia's land mass. In comparison, areas under paddy cultivation comprise only a meagre 672,000 hectares located in eight granaries (Fahmi et al. 2013). Moving forward will require Malaysia to boost domestic rice production by expanding the paddy areas to ensure greater self-sufficiency level.

### 3.4.2 Accessibility

Although FAO has classified Malaysia as a low vulnerable country concerning the right to access to food, the food price crisis in 2007/08 took the country by surprise. It had exposed Malaysia's vulnerability as a net rice importer when major producers such as Thailand and Vietnam decided to curtail their exports to ensure domestic food security (Tey and Radam 2011). To ensure accessibility for the poor during the 2008 food crisis, the Malaysian government had introduced the Miller Subsidy programme. This intervention entailed the provision of RM800 temporary subsidy for every metric tonne production of the lower grade ST15 percent broken rice from domestic paddy in Peninsular Malaysia at mill level from September 2008 until March 2009 (Tey 2010). Also, as a net food importer, the crisis affected Malaysia in terms of higher food import bills. In 2008, Malaysia's food imports totaled RM28 billion with major food imports being cereal and cereal preparations, cocoa, vegetables and fruits, dairy products and animal feed.

Consumer expenditure on food constitutes the largest share in Malaysia's consumer price index (CPI, 30.3 percent in 2010). In general, the lower the household income, the higher the proportion spent on food, housing, and utilities as a percentage

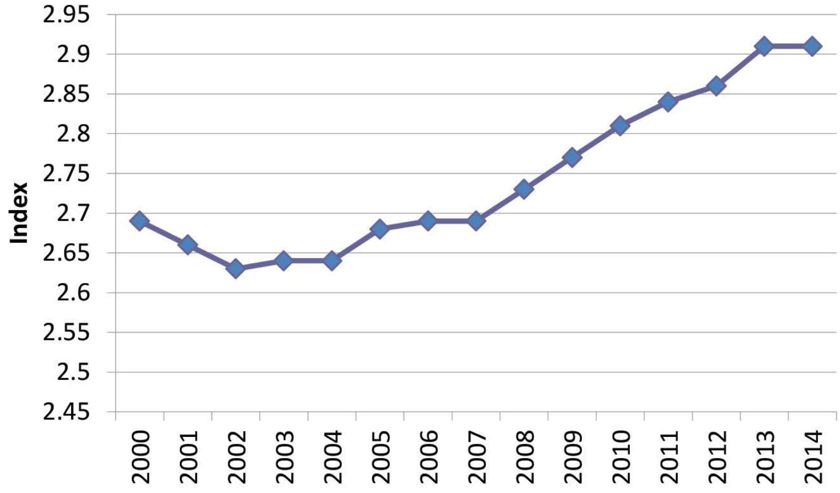



**Figure 3.6: Domestic Food Price level Index, Malaysia, 2000-2014**

**Source: FAOSTAT, 2016**

of total expenditure. During the food price crisis, the Malaysian government helped the consumers by introducing price control schemes for food items such as sugar, wheat, bread and cooking oil. The Domestic Food Price Level Index by FAO (Figure 3.6) also shows increasing food prices since 2007. In a study by Khazanah Research Institute (KRI 2014), accessibility to affordable food, especially protein like meat is shown to be a growing challenge to the lower income group.

### 3.4.3 Utilisation

The Food and Agriculture Organisation of the United Nations (FAO) estimates that fewer than 5 percent of the Malaysian population is under-nourished, which is considered to be not significant by international comparison (MoAAI 2008). However, Malaysia is facing the problem of over-nourishment with the prevalence of overweight and obesity is on the rise among both urban and rural populations (Sharif and Khor 2005). A study published in the medical journal *The Lancet* showed that 49 percent of women and 44 percent of men in this country were found to be obese.

### 3.4.4 Stability

Climate change is also likely to affect food production in Malaysia in the future, and by extension, its yield and food security as well. A 2°C rise in temperature is going to trigger a big change in agriculture and the future food scenario (Vermeulen et al. 2012). Malaysia's agricultural sector will be equally at risk, especially its key crops such as rice. According to the First National Communication Report, a rise in temperature may cause a reduction in rice yields (MOSTI 2000).

Equally damaging is a prolonged drought condition which may adversely impact the current flooded rice ecosystem (MOSTI, 2000). A study by Vaghefi et al. (2011) has reported that a 2°C temperature increase would decrease rice yield by 0.359 tons per hectare. Assuming the average price of RM1.10 for rice, Malaysia might suffer the average economic loss of RM162.531 million a year. A study by Al-Amin and Filho (2014) estimated that rice yield might decrease by up to 6.1 percent for every 1°C rise in temperature. Without any adaptation measures, national food security will be put at a greater risk. In the MADA granary area in Kedah, a total of 8,100 hectares out of 96,000 hectares of the paddy

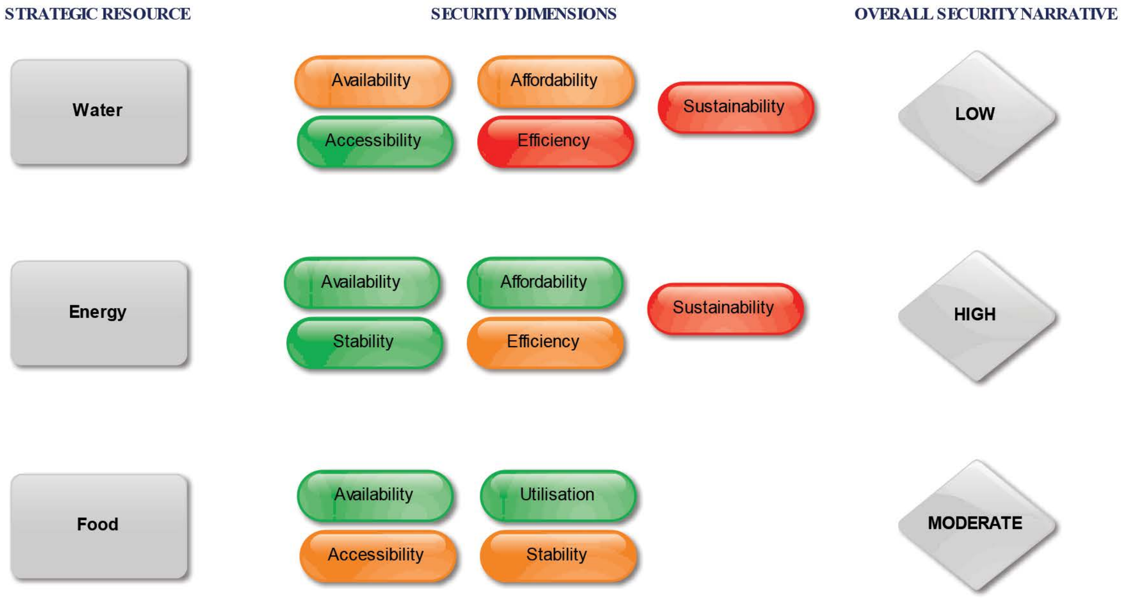



**Figure 3.7: Summary of Comparative Policy Responses on Water, Energy and Food Security**

cultivation area have become waterlogged and have required the repair and upgrade of infrastructure, compensation to farmers and rehabilitation of farmland, costing RM65 million.

## 3.5 CONCLUSION: POLICY RESPONSES

The preceding sections have discussed the various dimensions of water, energy and food security. It can be deduced that energy resources thus far received the highest-level policy attention from security's point of view. Malaysia's public policy on food security is modest in comparison with the energy sector but is better than policy measures put in place to ensure water security (Figure 3.7 illustrating the performance of security dimension in a 'traffic light' presentation). Given that water is crucial in ensuring continuous production of energy and food in Malaysia, its relative neglect from a security angle begs a more focused approach in terms of both planning and implementation.

The Eleventh Malaysia Plan (2015-2020) explicitly emphasises the need to move beyond the sector-based approach to advance water, energy and food security:

> "In the Eleventh Plan, Malaysia is breaking free from the conventional wisdom of development at all costs to green growth, which is a more sustainable path of growth. This will see Malaysia enter the ranks of advanced economies in 2020 with an economy resilient to the adverse impact of climate change and with a secure and sufficient supply of natural resources such as water, food, and energy. Partnership and shared responsibility across all levels of society, including individuals, will be key to safeguarding the environment and biodiversity. Successful green growth will not only expand economic opportunities, but also enhance inclusivity and reduce disaster risks." (Malaysia 2015: p.6-30)

Although there are clear interactions between water, food, and energy that may result in competition, synergies or trade-offs between different sectors or interest groups, the current planning, foresight and implementation of policies are still performed separately. Moving forward will require various stakeholders and policymakers to apply the nexus concept and tools which corroborates the need to view water, energy, and food as being complex and inextricably entwined.

### 3.5.1 Water Security Policy

In many countries, recognition of water security as a major societal challenge has been closely followed by a strong commitment to designing appropriate policy responses. In Malaysia, the security framing is relatively new in the water management sector. For decades following Independence, water availability in Malaysia has always been considered as generally safe for sustaining livelihoods, human well-being, and socio-economic development. Therefore, the security language was deemed unnecessary in the policy domain, except when discussing bilateral relations between Malaysia and Singapore or in confronting the ever increasing threat of floods disaster.

For many years since its Independence in 1965, Singapore supplied its water partly through daily transfer or import of 520,000 $m^3$ of raw water via pipeline from Malaysia. This transfer was encoded in two agreements between the two nations. The 1961 transfer agreement with Malaysia expired in 2011, and the 1962 agreement will expire in 2061, leaving Singapore to feel vulnerable to an interruption in its water supply from Malaysia mainly underpinned by the fear that raw water supply might be used as an instrument of foreign policy. This led scholars and observers analysing bilateral relations between Malaysia and Singapore often points to water as a potential issue that may spark violent conflicts between the two countries. Malaysia also shares the transboundary river of Sg Golok with Thailand's province of Narathiwat and with Indonesia through Sg Sibuku and Sg Sembakung in Tawau Sabah. But these two shared rivers were never discussed in the context of national security.

In recent years, the security narrative has gained more currency due to development pressures, water mismanagement, and climate change which has changed the water supply situation in Malaysia "from one of relative abundance to one of relative scarcity (Zakaria 2013: p.123). Realising the gap in sector-based water management, the Malaysian Government in February 2012 has formulated and endorsed the National Water Resources Policy (NWRP). The visionary shift is seen in its focus on *water as a resource*, away from the conventional way of equating water management solely with the water supply industry alone. NWRP outlines the various strategies and action plans to address the problems and concerns for both immediate and long-term to manage water resources availability and demand in the country. With the following policy statement, NWRP provides clear directions and strategies in water resources management to ensure water security and sustainability:

> "The security and sustainability of water resources shall be made a national priority to ensure adequate and safe water for all, through sustainable use, conservation and effective management of water resources enabled by a mechanism of a shared partnership involving all stakeholders."

One of NWRP's objectives explicitly aimed at setting out the "direction and strategies for collective action to ensure the security and sustainability of water resources through integrated and collaborative mechanisms involving all stakeholders at all levels."

### 3.5.2 Energy Security Policy

Malaysia underwent rapid economic growth in the past while enjoying energy independence as a net exporter. Under this condition, its energy security measures developed incrementally shaped by the policy landscape internationally and nationally. The earliest policy direction for the energy industry was formulated in 1975 following the *Petroleum Act 1974*. The National Petroleum Policy was formulated with the objective of bringing about efficient utilization of petroleum resources for industrial development as well as ensuring national control over the management and operation of the oil industry. In the later part of the 1970s when faced with the possibility of an extended oil crisis, Malaysia introduced the fuel diversification strategy into its National Energy Policy in 1979. This security-oriented policy was guided by three primary objectives, namely supply, utilisation, and environment. The supply objective aims to ensure the provision of adequate energy cost-effectively from indigenous non-renewable and renewable resources, yet securely by diversifying the resources. The utilisation objective seeks to utilise energy efficiently and productively. Finally, the policy also aims to minimize the negative impacts of energy production, transportation, conversion, utilization and consumption on the environment.

Malaysia's fuel diversification policy is reviewed from time to time to ensure that the country is not over-dependent on one main energy source. In subsequent years Malaysia introduced the National Depletion Policy in 1980 and the Four-Fuel Diversification Strategy in 1981. The aim of the former was to safeguard the country's finite and non-renewable petroleum resources from over-exploitation in the long run while the later intended to pursue the balance utilisation of oil, gas, hydro and coal.

The utilisation of renewable resources such as biomass, solar, mini-hydro, etc. began to be encouraged with the formulation of the Five Fuel Policy in 2001 under the framework of the Eight Malaysia Plan (2001-2005). The policy places renewable energy as the country's fifth fuel on par with oil, gas, hydro, and coal for grid-connected power generation. Also, in recent years the Malaysian government seeks to forestall net energy import dependency by moving into non-conventional oil and gas reserves. It aims to do this by exploring for more fields, developing the small fields already discovered but as-yet undeveloped, and by extracting more from already producing fields employing enhanced-oil-recovery techniques. PETRONAS is developing an emergency response plan and a security code to deal with the possibility of failures in gas supply infrastructure.

The latest energy policy was formulated in 2010 under the Tenth Malaysia Plan. The New Energy Policy expands on the energy security dimension by including economic efficiency as well as factoring in social and environmental considerations in its five strategic pillars. These pillars include rationalising energy pricing gradually to match market price, undertaking a more strategic development of energy supply by diversifying energy resources, accelerating the implementation of energy efficiency initiatives in the industrial, residential and transport sectors, improving governance to support the transition to market pricing, and ensuring that the New Energy Policy is implemented based on an integrated approach.

Malaysia also participates in regional energy cooperation to ensure its energy security. It is a party to a regional effort to build Trans-ASEAN Gas Pipeline (TAGP) system. TAGP envisages the establishment of the transnational pipeline network linking major natural gas producers and consumers throughout the South East Asia. Malaysia has also expanded the gas exploration and development to the regional natural gas trading market, in the joint co-operation of Trans-Thailand–Malaysia Gas Pipeline System. This allows Malaysia to pipe natural gas from the Malaysia–Thailand Joint Development Agreements (JDA) to its domestic pipeline system.

Malaysia is also a participant in the ASEAN Power Grid (APG) system. Regional interconnected electricity networks allow ASEAN members with abundant electricity capacity to generate income from their surplus power while countries with power shortages can import from neighbouring countries at reasonable prices. The APG has benefited not only Malaysia's electricity supply stability but also the neighbouring countries' especially in meeting their respective peak demand from the Peninsular Malaysia-Thailand Interconnection and Peninsular Malaysia-Singapore Interconnection.

### 3.5.3 Food Security Policy

Food security policy in Malaysia is tightly linked to rice availability, accessibility, and utilisation. A protectionist regime from supply and price shocks has been put in place since the 1970s to ensure high price to paddy farmers to produce rice, achieve a reasonable level of self-sufficiency, and guarantee a stable and high quality of rice to the consumers (Arshad and Hamed 2010). Most of the efforts are carried out with market instruments such as input and output subsidies, price control at farm and retail, licensing and import monopoly. Also, between 1980 until October 2009, the government spent a whopping RM9.6 billion on cash subsidies on paddy farmers. To facilitate the stabilisation of prices, the government has been keeping a rice stockpile of 92,000 metric tonnes since the Colonial period in 1949. At the same time, this self-reliance approach has been complemented with the trading strategy;

rice imports from the global market were once important in determining Malaysia's food security.

However, the high prices during the 2007-2008 food crises have exposed Malaysia's vulnerability as a rice importing country. Around that period, the SSL for Sabah and Sarawak, for instance, was low, revolving around the figures of 30 percent and 53 percent respectively. At the height of the crisis, Malaysia introduced the National Food Security Policy to boost domestic production to strengthen its self-reliance approach to addressing food insecurity. The SSL for rice production in Malaysia was set to increase to 70 percent by 2010, aiming for an increase in average yield from 3.47 metric tonnes per ha in 2005 to 4.48 metric tonnes per ha in 2010. The government also announced new paddy farming areas amounting to 23,017 ha in Sabah and 25,583 ha in Sarawak. The national rice stockpile was set to 239,000 metric tonnes for 45 days with a distribution of 78 percent for Peninsular Malaysia, 12 percent for Sabah and 10 percent for Sarawak (Tey 2010). In addition to rice, fisheries, livestock, and vegetables began to receive more attention as strategic commodities for the country's food security.

The government also saw the need revise the national rice stockpile management. With BERNAS (PadiBeras Nasional Berhad, a corporate entity) entrusted as the country's sole rice importer, Malaysia has also increased its stockpile to 292,000 metric tonnes (from 92,000 metric tonnes) at any one time. More recently, BERNAS moved to stabilise supplies by signing a Memorandum of Understanding with Vietnamese authorities to secure 800,000 metric tonnes of rice when the need arises. These measures collectively represent the breadth of the government's commitment to ensuring food security for its citizens.

# 4 STATE LEVEL WATER-ENERGY-FOOD SECURITY

## 4.1 BACKGROUND

Resources are the building blocks for socio-economic development. However, there are many trade-offs countries must cope with, and synergies to benefit from in optimising the use of different resources. For example, a country's policy to exploit its abundant energy resources may contradict its climate strategies and water security targets. The current international interest in water, food, and energy nexus presents a policy window to put in place systemic changes that embolden integrated resource management. An increased capacity to manage the system interlinkages is central to bridge existing and future resource challenges (Hoff 2011; Bazilian et al. 2011).

The resource resurgence and symptoms of scarcity beg the question whether Malaysia has moved from a period of resource cornucopia that fuelled its first few decades of rapid development to one that is characterised by resource scarcity. If so, Malaysia is now at a crossroad as increased pressure both socially and environmentally demands an institutional redesign to respond to the new challenges.

At the state level, fragmented sectoral responsibilities, lack of coordination, and inconsistencies between laws and regulatory frameworks may lead to misaligned incentives. Currently, there is only rudimentary understanding of the complex and pervasive connections between water, food and energy security in Malaysia. This gap is true for both the two-way (e.g., food-water and energy-water) and three-way (water-food-energy) nexus interactions. More seriously, there is also insufficient recognition of the security dimensions of these individual resources, be it by the academic or policy communities.

## 4.2 WATER-FOOD NEXUS

Agriculture is the largest consumer of water in the global economy. Crops and livestock need water to grow. Water is an input for producing agricultural goods in the fields and along the entire agro-food supply chain which includes farmers, transporters, storekeepers, food processors, shopkeepers, and consumers. Agriculture uses approximately 2,500 trillion litres of water each year. Regrettably, agriculture also wastes 60 percent or 1,500 trillion litres of the water it consumes (Clay 2004). There are many synergies and trade-offs between water and food production. Using water to irrigate crops might promote food production, but it can also reduce river flows. Significant changes in policy and management, across the entire agricultural production chain, are needed to ensure the best use of available water resources in meeting growing demands for food and other agricultural product.

### 4.2.1 Water for Irrigation

Malaysia uses about 75 percent of the available water resources for irrigation. Out of 600,000 hectares of rice cultivation areas, 50 percent are irrigated for double-cropping while the rest, mainly in Sabah and Sarawak are rain-fed (Lee et al. 2005). Irrigation efficiency varies with 50 percent in the larger irrigation systems and less than 40 percent in smaller schemes (Toriman and Mokhtar 2012). Other challenges include competition with the rising consumer demand in industrial and domestic sectors, inefficient water usage, low water productivity of rice crop and poor maintenance of aging irrigation infrastructures.

**Table 4.1: Potential Irrigation Water Saving in the Granaries**

| No | Existing Granaries | Basin (RBMU) | Area (ha) | Present Efficiency | Irrigation Water Use (MCM per Year) | Target Efficiency (percent) |
|---|---|---|---|---|---|---|
| 1 | MADA | Kedah – Muda | 96,558 | 70 | 1589 | 75 |
| 2 | KADA | Kelantan | 31,464 | 55 | 659 | 75 |
| 3 | a. Kerian IADA | Kerian | 22,170 | 50 | 511 | 75 |
| | b. Sungai Manik IADA | Perak | 6,278 | 50 | 145 | 75 |
| 4 | North West Selangor IADA | Bernam | 19,701 | 50 | 454 | 75 |
| 5 | Pulau Pinang IADA | Muda | 10,138 | 50 | 234 | 75 |
| 6 | Seberang Perak IADA | Perak | 8,529 | 50 | 197 | 75 |
| 7 | Kemasin Semerak IADA | Kemasin/Semerak | 5,560 | 50 | 128 | 75 |
| 8 | KETARA (Besut) IADA | Besut | 5,110 | 50 | 118 | 75 |
| 9 | Pekan IADA | Pahang | 10,937 | 50 | 252 | 75 |
| 10 | Rompin IADA, Pahang | Rompin | 6,173 | 50 | 142 | 75 |
| 11 | Batang Lupar IADA, Sarawak | Lupar | 4,300 | 50 | 99 | 75 |
| 12 | Kota Belud IADA, Sabah | Bongan | 3,357 | 50 | 77 | 75 |
| Total | | | 230,275 | 50 | 4,604 | 75 |

**Source: ASM, 2015.**

Improved efficiency in the use of water is essential for future food security in Malaysia concomitant with the need to increase rice production (Ghazali 2004). A saving of 5 percent in irrigation water can meet 15 percent of water demand for the domestic and industrial sector (Table 4.1). In a study by Academy of Sciences Malaysia (2015), efficiency measures if put in place in matured granaries such as MADA, Pulau Pinang IADA, and Kerian IADA have the potential to save 972 MLD of freshwater needs. This saving represents a substantial relief to the freshwater supply in such a water-stressed region. The potential savings from 12 granaries in 2050 is equivalent to 2927 MLD, which can be used in the water supply sector.

Apart from improving water-use efficiency in irrigated agriculture intending to produce `more crop less drop,' a nexus solution will also aim for improving the efficiency of crop utilisation of water (Abdullah 2006). Different crops use a different amount of water for its survival. Rice in Malaysia consumes 3000 litres for every 1kg yield, whereas cocoa and rubber use between 10,000 to 20,000 litres of water for every 1 kg of crop yield. Malaysia's major commodity, oil palm, requires 550 litres of water for every 1 kg yield and an additional 4,000 litres of water to extract and process oil from seed palm bunches. Further, much of the emphasis under the food-water nexus focused on the quantities of water input for food production. Equally important to that function is that the quality of or polluted irrigation water can also affect food security.

The effect of food-water nexus is emerging in some localities in Malaysia. In the case of Muda and Pedu Dams in Kedah, logging activities at the Ulu Muda forest reserve will be most likely to cause

**Table 4.2: Demand for Water from Muda River, 1995**

| Sector | Gross Demand (mil $m^3$) | Requirement from the Muda River (mil $m^3$) |
|---|---|---|
| **Irrigation** | | |
| Muda | 1,977 | 1,391 |
| Balik / Seberang | 156 | 80 |
| Others | 433 | 216 |
| Subtotal | 2,566 | 1,687 |
| **Domestic & Industry** | | |
| Kedah | 129 | 136 |
| Penang | 166 | 194 |
| Perlis | 9 | 9 |
| Subtotal | 313 | 339 |
| Total | 1,991 | 2,896 |

**Source: Lee, 2009.**

siltation which may eventually affect the storage capacity of the two dams. If the water issue is left unchecked, rice production could suffer as a result. Also, the State of Penang is also dependent on Sg Ulu Muda as one of its sources of raw water supply (Table 4.2). In 2015, with dams on the island running on low storage because of record low rainfall since February, the state of Penang will have to rely more on water sources from the Ulu Muda river. This dependence will again beg for trade-off with the food production capacity in the state of Kedah. The case presents a two-at-a-time nexus challenge between water and food sectors.

### 4.2.2 Water for Fruits and Vegetable Production

The National Agro-Food Policy (2010-2020) covers 20 types of fruits and 22 types of vegetables. Eight major fruits given more emphasis for domestic as well as for export markets are pineapple, papaya, watermelon, starfruit, banana, citrus, mangosteen and durian. The total area planted with fruits in Malaysia in 2013 is about 202,593 ha (Table 4.3) (MoAAI 2014). For vegetables, the total area planted increased to 61,297 ha in 2014 from 39,139 ha in 2010. The production is at 1.54 million tonnes and export value of USD127.8

**Table 4.3: Planted Area and Production of Fruits By Region, 2009-2013**

| Region | 2009 | | 2011 | | 2013 | |
|---|---|---|---|---|---|---|
| | Planted area (ha) | Production (tonne) | Planted area (ha) | Production (tonne) | Planted area (ha) | Production (tonne) |
| Peninsular Malaysia | 194,452 | 1,257,498 | 171,867 | 1,283,552 | 150,033 | 1,235,564 |
| Sabah | 17,447 | 142,322 | 17,546 | 156,172 | 17,087 | 131,176 |
| Sarawak | 37,690 | 200,878 | 37,107 | 181,988 | 35,131 | 176,407 |
| Total for Malaysia | 249,994 | 1,602,668 | 226,781 | 1,623,532 | 202,593 | 1,544,718 |

**Source: Ministry of Agriculture and Agro-Based Industry, 2014.**

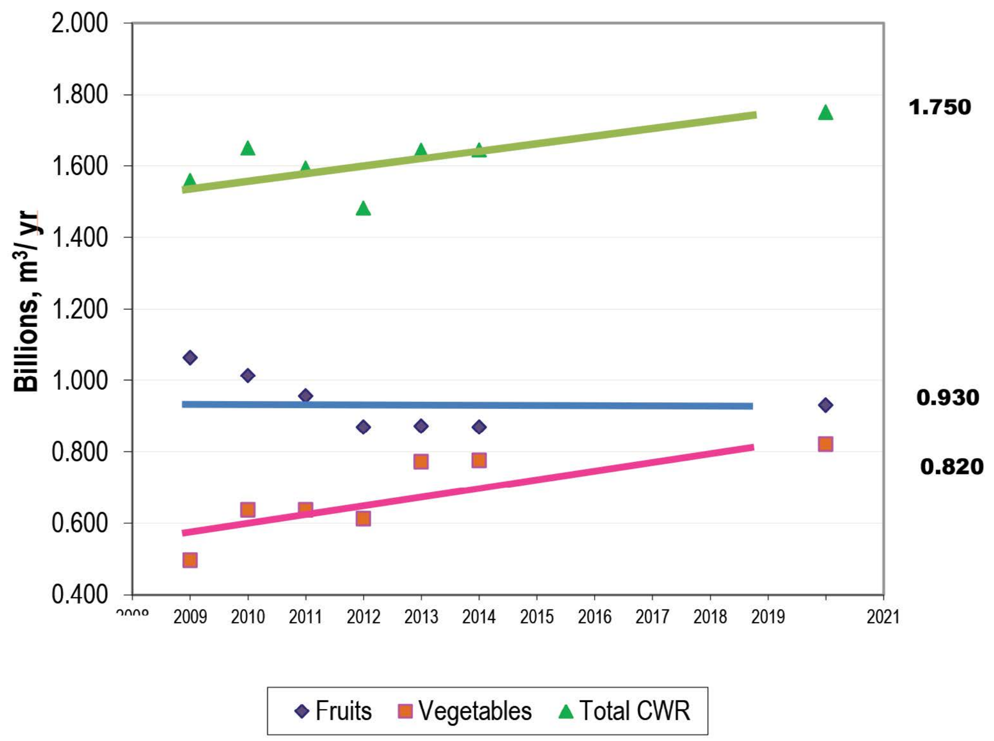



**Figure 4.1: Trend of Crop Water Requirements, 2009-2021**

**Source: Department of Agriculture, 2015.**

million to mainly Singapore, Hong Kong, and the Middle East.

Water management is crucial to vegetable and fruit crop management since water is an essential component of photosynthesis, respiration, absorption, and translocation. With reduced water uptake, carbohydrate production, the building block of plant nutrition, is significantly decreased. This limits plant growth and vigour.

By 2020, Ministry of Agriculture and Agro-Based Industry estimated that crop water required (CWR) for fruits and vegetables would revolve around 2.0 Billion $m^3$/year of clean water (Figure 4.1). The irrigation demand is estimated at 1.0 billion $m^3$/year by assuming 50 percent of CWR is supplied by rainfall and available water in the soil. It must be noted that different crops have different water requirements.

Moving forward will require the following measures to be taken. First, good agricultural practices and modern irrigation technology will need to be used to improve the irrigation efficiency. Second, awareness of water usage in agriculture should be emphasised to sustain the industry and harmony with other water competitors such as domestic and industrial sectors. Finally, continuous improvement of water quality through research and development is a necessity to secure quality water for fruit production.

### 4.2.3 Water for Livestock

The Malaysian livestock industry is an important and integral component of the agricultural sector, providing gainful employment and producing useful animal protein food for Malaysians. The total ex-farm value of livestock products in 2013 was RM 14.78 billion. The country has achieved more than 100 percent self-sufficiency (SSL) in poultry industries whereas the SSL for ruminant products is still below 30 percent. The state of Johor is the largest livestock producer in the country (Table 4.4).

**Table 4.4: Population of Animals in Different States of Malaysia, 2013**

| States | Cattle and Buffalo | Sheep and Goat | Swine | Chicken and Duck |
|---|---|---|---|---|
| Johor | 117,321 | 86,674 | 254,525 | 61,602,591 |
| Kedah | 76,967 | 57,871 | 725 | 42,816,340 |
| Kelantan | 103,328 | 76,362 | 675 | 1,692,854 |
| Melaka | 31,052 | 52,412 | 47,195 | 19,815,851 |
| N Sembilan | 47,038 | 60,231 | 916 | 17,907,022 |
| Pahang | 143,606 | 53,595 | 3,600 | 12,723,149 |
| P Pinang | 14,880 | 14,179 | 330,840 | 12,472,288 |
| Perak | 66,898 | 23,417 | 512,850 | 41,919,332 |
| Perlis | 6,761 | 5,253 | 90 | 1,192,440 |
| Selangor | 23,269 | 23,417 | 273,894 | 19,607,828 |
| Terengganu | 99,976 | 5,253 | n.a | 5,592,764 |
| Kuala Lumpur | 491 | 23,417 | n.a | n.a |
| Sabah | 120,366 | 52,673 | 82,472 | 5,498,110 |
| Sarawak | 22,690 | 16,955 | 335,171 | 39,302,243 |
| TOTAL | 1,607,230 | 1,082,612 | 3,268,263 | 519,485,271 |

**Source: Department of Veterinary Services, 2015**

**Table 4.5: Estimated Average Daily Water Consumption for Livestock Animals in Malaysia**

| Animals | Average Weight (kg) | Drinking Water (Litres/Animal/ Day) | Animal Populations | Estimate Water Daily Consumption (ℓ) |
|---|---|---|---|---|
| Cattle & Buffalo | 200 | 25 | 1,057,736 | 26,443,400 |
| Goat & Sheep | 30 | 11 | 713,171 | 7,844,881 |
| Swine | 120 | 28.3 | 1,813,695 | 51,327,568 |
| Chicken & Duck | per 100 animals | 30 | 244,705,730 | 73,411,590 |

**Source: Department of Veterinary Services, 2015.**

**Table 4.6: Sales of Electricity (GWh), Malaysia, 2008-2013**

| Sector | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|
| Agriculture | 214 | 240 | 265 | 306 | 344 | 375 |
| Domestic | 15,810 | 16,792 | 18,217 | 18,916 | 20,301 | 21,601 |
| Commercial | 26,939 | 27,859 | 29,872 | 31,755 | 33,218 | 34,878 |
| Industry | 40,511 | 36,261 | 40,071 | 41,449 | 42,047 | 42,721 |
| Public Lighting | 956 | 1,078 | 1,046 | 1,139 | 1,235 | 1,302 |
| Mining | 34 | 47 | 62 | 75 | 98 | 121 |
| Export (EGAT) | 1,152 | 166 | 88 | 73 | 13 | 17 |
| Total | 85,616 | 82,443 | 89,621 | 93,713 | 97,256 | 101,105 |

**Source: Energy Commission, 2013**

Providing enough quality water is essential for good livestock husbandry. The daily water requirement of livestock varies significantly among animal species. Water usage in livestock involves the following three activities, namely, drinking and farm cleaning/servicing; product processing; and feed production. For example, the water requirement for dairy cattle and buffalo farm maintenance involves cooling at 125 litres/day/head and feed equipment cleaning at 11.5 litre/day/head (Table 4.5). The highest daily water consumption is on pig farms. As Malaysia steps up its effort to improve its SSL for livestock, more research is needed to promote water management in the industry.

## 4.3 ENERGY-FOOD NEXUS

Energy has always been essential for the production of food. Modern agricultural production practices rely heavily on energy inputs that have led to a dramatic increase in fossil fuel use. Even though the use of energy in agriculture sector is not as high as in other sectors, it is important to study the connectedness between the two sectors (Table 4.6). From 46,711 ktoe of Malaysia's final energy consumption in 2012, the agriculture and forestry sectors used 2.3 percent (Energy Commission 2014). With food production rising sharply, more energy-hungry machinery such as tractors and cultivators will be used for agricultural activities in the future. An input-output analysis by Bekhet and Abdullah (2010) shows a significant increase of energy consumption in agriculture for the period of 1991 to 2000. It was also found that the value of total energy use in the agricultural sector jumped to 5.4 percent in 2000 from 1 percent of energy input in 1991.

The nexus challenge is how to make the food system more energy efficient. The average overall energy efficiency of Malaysia's agriculture sector is 20 percent within the period of 1991 to 2009. This figure is found to be higher than countries like Turkey but lower than efficient economies such as Norway and Japan (Ahamed et al. 2011). One of nexus solutions to reduce energy consumption in the food system is to focus on innovative storage and distribution which may minimise energy wastage along the supply chain. Another solution is to incentivise consumers and businesses to reduce the burgeoning food waste or turn them into energy. Another nexus choice is to use paddy residue to generate electricity as opposed to the current practice of disposing of them by open burning with many unwanted health and environmental consequences. In 2011 the production of rice straw in Malaysian fields was 1,933,889.3 tonnes with Kedah as the largest producer (Shafie et al. 2014).

## 4.4 WATER-ENERGY NEXUS

Water is a key input into the production of energy. Therefore, the energy security of countries is closely linked to the availability of their water resources. A lot of energy is consumed in the supply of water in various parts of the world. The two sectors – water and energy – are hence inextricably linked, but often understated in policy and practice (Olsson 2012).

Huge amounts of water are required to produce the primary energy sources such as oil, gas, coal, and uranium. Similarly, electricity generation also leaves a big water footprint, with different types of thermal electric power plants consuming different volumes of water (Pate et al. 2007). For example, for their open loop cooling process, nuclear power stations require from 25,000 to 60,000 gallons per MWh whereas natural gas combined cycle power plants withdraw from 7,500 to 20,000 gallons per MWh. In contrast, a plant using coal integrated gasification combined cycle technology requires only around 200 gallons per MWh.

In 2010, energy costs contributed 65.5 percent of total expenses for the Tenaga Nasional Berhad (TNB) Group. For the financial year of 2010, energy cost grew by 2.4 percent to RM17,379.0 million from RM16,974.4 million recorded in 2009. The increase in energy costs was mainly due to higher payment to Independent Power Producers (IPP), totaling RM12,528.0 million, an increase of 5.9 percent compared to the previous financial year. However, lower fuel costs incurred during the year somewhat offset the increase in IPP purchases. Fuel costs showed a reduction of 5.8 percent to RM4,851.0 million in 2010 contributed to lower average price of coal at USD88.2/mt compared to USD90.2/mt in 2009, primarily due to the appreciation of Ringgit against US dollar (TNB Annual Report 2010: p69).

### 4.4.1 Water for Energy Production

Thermal cycle plants require significant amounts of water for steam, cooling, and condensation. Malaysia operates many thermal power plants with significant impact on water withdrawal. Not only does water use vary according to power generation plant-type, cooling technology, age and operational efficiency, it also varies according to fuel production process, geography and climate. Water consumption in two power plants with different installed capacity but both using natural gas fuel can differ as shown in Table 4.7 and Table 4.8.

**Table 4.7: Water Consumption and Bill for the Paka Gas Turbine Power Station.**

| Year | Station Total Capacity (MW) | Water Consumption ($m^3$) | Annual Water Bill (RM) |
|---|---|---|---|
| 2011 | 1016 | 253417 | 486584.55 |
| 2012 | 1007 | 253726 | 498765.25 |
| 2013 | 1028 | 388504 | 590825.15 |
| 2014 | 1006 | 338525 | 530266.45 |
| 2015 | 1004 | 495785 | 620510.45 |

**Source: TNB**

**Table 4.8: Water Consumption and Bill for the Tuanku Jaafar Station, Port Dickson.**

| Year | Station Total Capacity (MW) | Water Consumption ($m^3$) | Annual Water Bill (RM) |
|---|---|---|---|
| 2011 | 1500 | 485,313 | 776,500.62 |
| 2012 | 1500 | 435,493 | 696,788.81 |
| 2013 | 1500 | 292,016 | 467,225.20 |
| 2014 | 1500 | 324,731 | 519,569.80 |
| 2015 | 1500 | 264,196 | 622,954.41 |

**Table 4.9: Total Freshwater Withdrawal in PETRONAS Oil and Gas Operation**

| | Total Freshwater Withdrawal (million $m^3$ per year) | | |
|---|---|---|---|
| | 2012 | 2013 | 2014 |
| Upstream | 2.23 | 2.17 | 2.93 |
| Downstream | 45.81 | 44.47 | 46.32 |

**Source: PETRONAS 2013, 2014**

Oil and gas production (O&G) has a large water footprint. Water is needed for the extraction of oil from underground sources (upstream) as well as for the refining of the crude oil (downstream). To meet an increasing water resource demand in the O&G sector, PETRONAS has been promoting efficient use of water across its national and international operation. Table 4.9 shows PETRONAS' total upstream and downstream water withdrawal. One example of its efficiency initiative, which is part of PETRONAS Corporate Sustainability Framework, is the reduction initiative based on the 3R (reduce, reuse, recycle) principle applied at the Centralised Utilities Facilities Kertih in Terengganu (PETRONAS 2013, 2014). Efficiency measures put in place has improved the facility's reverse osmosis systems with a recovery rate of up to 80 percent reduced water losses or an equivalent to 75 to 100 cubic metres per hour.

### 4.4.2 Energy to Move Water

The water industry is energy-intensive. Electrical energy use for water and wastewater operations is relatively small, usually of the order of one percent of the national consumption (Olsson 2012). Although this figure is arguably low to solve the global energy crisis, the energy costs for pumping, treating and moving large volumes of water are an increasing and significant part of the operating costs.

According to Malaysia Water Industry Guide 2013, the average cost of energy cost to operating expenditure (OPEX) in Malaysia is about 25 percent in 2012. In 2014, the figure rose to 27 percent (Malaysian Water Association 2015). Among the states, Perlis, Negeri Sembilan, and Pahang recorded the highest energy cost-to-OPEX ratio at 56, 42, and 38 percent respectively. A former senior official of the Penang Water Authority (PBA) summarised the nexus issue of relying on energy-intensive inter-basin water transfers as solutions to water scarcity:

> "… we are looking into the need to tap water from further and further sources from our cities. The prospect of transport of water over distances of 100km is a growing reality. It requires about 0.4kwHr of electric energy to raise water through 100 meters. At RM0.18 per kwHr, this translates to energy costs of 7 cents per metre cube of water. This is our present cost. The prospect of this becoming 20 cents is near."

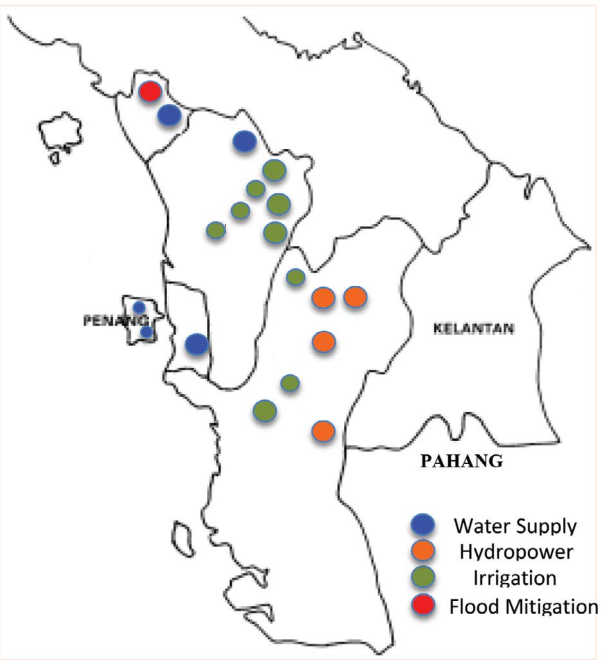
It is crucial to understand and quantify the energy use for the water supply for the development of integrated policies that ensure the sustainable use of both resources.

Transporting water is an essential operation whereby water is moved from the source like rivers or lakes to some treatment. Within the water treatment plant, water has to be moved around various unit processes. Pumping is a major part of the cost to bring drinking water to the consumers and later from the consumers to the wastewater treatment plant. Puncak Niaga Sdn Bhd, a major water treatment company, operating in Selangor, requires energy consumption for its pumping systems. From 2010 to 2011, there was an increase of 0.92 percent as a result of the increase from a 1.63 percent increase in the volume of water produced. The water distribution company SYABAS also consume electricity in driving its 498 pumping stations. In the Selangor state, many efficiency measures were taken at Sg Selangor P2 water treatment plant to reduce the cost energy in supplying water:

- Reuse sampling water for WTP usage at Filtration Plant with estimated saving of RM127,334.00 per year
- Decommission coagulation mixers at coagulation process Actiflo Plant with estimated saving of RM80,210.00 per year

## 4.5 HYDROPOWER

Water storage in the form of dams serves many purposes. They are built to control flood, store water for irrigation, recreation, and drinking water, as well as for generating electricity. Hydropower generation meets 16 percent of the world's power needs and has been one of the main driving forces behind the construction of 45,000 large dams worldwide (WCD, 2000). Malaysia currently has 66 large single- and multi-purpose dams and many more on the drawing board (Ismail 2014; Aiken and Leigh 2011). In 2009, the Department of Irrigation and Drainage alone managed 16 dams for flood mitigation, providing adequate irrigation water and controlling silt while other dams are under the jurisdiction of other agencies (see Figure 1.2). However, these different water uses come along with conflicting demands on water utilisation leading to trade-offs which highlight the need for an integrated management plan for all catchments.




Hydropower converts the natural flow of water into electricity. With a fair amount of sunshine, and a high rainfall rate well distributed throughout the year, Malaysia poses an ideal and substantial potential for the hydropower generation. The hydropower potential in Malaysia is estimated at 29,000-MW, with 85 percent located in the East Malaysia. Hydropower potential in the Peninsula is much more limited with only two major dams to be commissioned by 2016 (Hulu Terengganu 265 MW and Ulu Jelai 372 MW) and two multi-purpose dams in Kelantan under advanced planning. By the end of 2013, only 3,931 MW (13.2 percent of total installed capacity) of the resource has been fully utilised (with the share of energy input in hydropower stations of 8.7 percent from the total 30,959 ktoe) (Energy Commission 2013). This is basically due to the high capital investment required for its development (Table 4.10).

### 4.5.1 Costs and Benefits of Hydropower

The Eleventh Malaysia Plan emphasises water, energy and food security recognising the fact that actions in one area more often than not have impacts on one or both of the others. Hydropower development presents a quintessential three-way interaction of the nexus security challenge. The establishment and operation of hydropower dam are overwhelmingly complex because the issues are not only confined to the design, construction and operation of dams themselves but embrace the issues of social, environmental and political perspectives.

Dam development for hydropower therefore often involves many trade-offs. Although the generation of electricity impacts little on the quantity of water it may alter the timing of stream flows since the timing of water releases is determined by the demand curve for electricity managed by the National Load Despatch Centre (NLDC). Conflicts can also arise between hydropower and downstream

**Figure 4.2: Dams in the Northern States of Peninsular Malaysia.**

**Source: Hezri 2016.**

**Table 4.10: Installed Capacity of Major Hydro Power Stations**

| | Station | State | Installed Capacity (MW) | Total (MW) |
|---|---|---|---|---|
| 1 | Stesen Janaelektrik Sultan Mahmud Kenyir | Terengganu | 4x100 | 400.0 |
| 2 | Stesen Janaelektrik Temengor | Perak | 4x87 | 348.0 |
| 3 | Stesen Janaelektrik Bersia | | 3x24 | 72.0 |
| 4 | Stesen Janaelektrik Kenering | | 3x40 | 120.0 |
| 5 | Stesen Janaelektrik Chenderoh | | 3x10.7 + 1x8.4 | 40.5 |
| 6 | Stesen Janaelektrik Sg Piah Hulu | | 2x7.3 | 14.6 |
| 7 | Stesen Janaelektrik Sg Piah Hilir | | 2x27 | 54.0 |
| 8 | Stesen Janaelektrik Sultan Yussuf, Jor | Perak | 4x25 | 100.0 |
| 9 | Stesen Janaelektrik Sultan Idris II, Woh | | 3x50 | 150.00 |
| 10 | Stesen Janaelektrik Odak | | 4.8 | 4.8 |
| 11 | Cameron Highlands Scheme | Pahang | 0.8+0.5+0.9+5.5 | 7.7 |
| 12 | Pergau | Kelantan | 4x150 | 600 |
| 13 | Kenerong Upper | | 2x6 | 12.0 |
| 14 | Kenerong Lower | | 2x4 | 8.0 |
| 15 | Tenom Panggi | Sabah | 3x22 | 66.0 |
| 16 | Batang Ai | Sarawak | 4x27 | 108.0 |
| 17 | Bakun | | 300x8 | 2400.00 |
| | | | Total | 4,505.6 |

**Source: TNB 1993; Energy Commission, 2014 (modified)**

uses, including irrigation and supporting ecosystem services. In Malaysia, in the interest of energy security, hydropower dams such as Bakun have affected the food and water security of more than 9000 Sarawak indigenous communities (Aiken and Leigh 2011). The local communities resettled to Kampung Ganda from the remote villages of the Temengor Lake were provided with 11 acres of land with rubber trees to each household involved (Choy and Othman 1996).

Some people consider hydropower a type of renewable energy because it does not consume fossil fuels. Instead, it harnesses the power of renewable supplies of water by running through the turbines and discharging it downstream. While often praised for its low GHG emissions, it is widely accepted now that hydropower negatively affects water resources and river or lake ecosystems. By impounding a river or diverting its flow, dams alter the natural regime of a river, compromise the habitat functions the river plays for fish, modify water quality and change the river bed dynamics.

It is often said that consumptive water use does not happen in hydropower generation because what is required to generate power is water pressure and not the water itself. However, since water stored in a dam in a warm country faces regular temperature increase, water loss from the surface of hydro dams in Malaysia is inevitable. This evaporation process contributes to the consumptive aspect of dam storage which results in less flow for downstream uses. In a recent study of national water demand, total potential evaporation is estimated to be around 1.25 MCM/km$^2$/year or 3.42 MLD/ km$^2$. The total losses from hydropower surfaces in Malaysia are estimated to be 2000 MCM/year or 3.872 MLD (Akademi Sains Malaysia 2015).

On the positive side, hydropower can be a desirable form of electrical power generation from a power grid point of view. Its electrical power output can be changed within minutes, and this makes hydropower the preferred source for frequency control (around 49.75 to 50.2 in Peninsular Malaysia). Infrastructure costs aside, hydropower is economical since the fuel is rainwater from the sky, which is technically free. Both features render hydropower to be placed third in the electricity generation merit order in Malaysia as illustrated in Figure 4.3. If hydropower plants are unable to provide electricity during peaking, power stations with the gas turbine open cycle will have to generate power at higher marginal costs to the national grid.

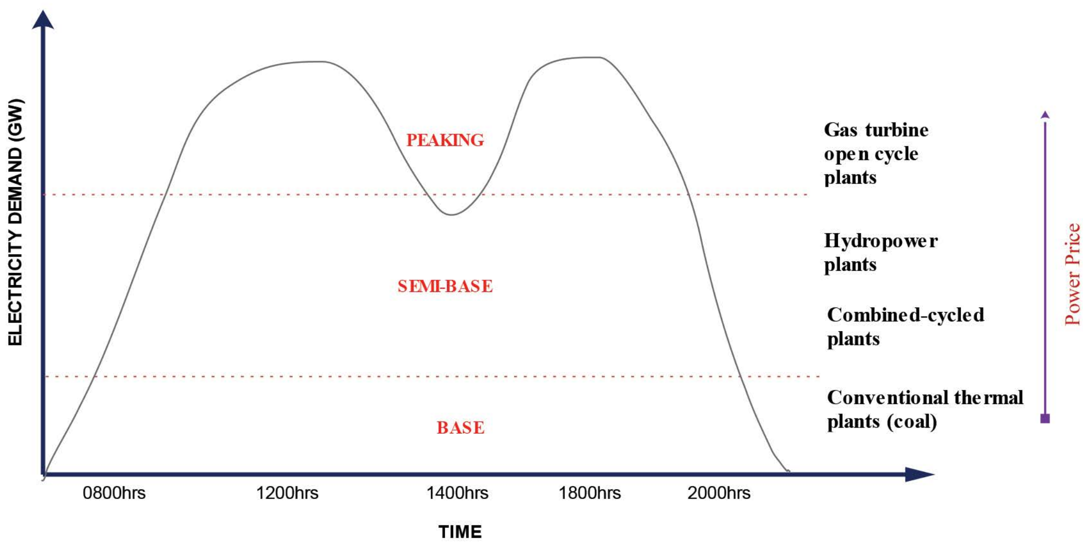
Alienating land for hydropower generation can be a lucrative source of income for state governments in Malaysia. Compensation from a utility company such as TNB to a state government is paid according to the units of electricity generated rather than by actual measurement of flow through the turbines (TNB 1993). The following considerations also determine the value of the compensation for the states involved in hydropower:

- Premium for alienated land
- Compensation for timber loss
- Quit rent for alienated land
- Payment for water use
- Impounding fee for water storage

A nexus solution needs to look at multiple issues and quantify those social and environmental trade-offs against economic benefits right from the early stages in the planning of a dam.

### 4.5.2 Kenyir Dam in Terengganu

The 400 MW Sultan Mahmud Power Station and its 155-metre height impounding Lake Kenyir is Peninsular Malaysia's largest storage hydropower scheme. Kenyir is a multi-purpose hydropower station which incorporates power generation, flood and drought prevention, recreation, tourism and aquaculture (TNB 1993). Before the construction of the dam, the East Coast used to flood each year around December to January. One of the benefits of




Demand for electricity changes throughout the day. The peak demand often occurs in late afternoon. Demand is usually met by a combination of continuous base load power and additional power from other sources. The power price is determined by the 'generation merit order'. According to this ascending sequence of price, power plants with the lowest marginal costs are the first ones to be brought online to meet electricity demand

**Figure 4.3: Electricity Generation Merit Order**

regulating Sg Terengganu is that the Kenyir dam has provided flood mitigation function successfully since the beginning of its operation. The other important function it provides is to minimise the interruption of the freshwater supply at Kuala Terengganu. Since the Sg Terengganu river basin is mainly flat, it faces the risk of saltwater intrusion into the freshwater supply when high ocean tides coincide with low river flow. The Kenyir hydropower scheme showcases a best-practice attempt of both upstream and downstream Terengganu river basin stakeholders such as TNB and Syarikat Air Terengganu (SATU) to cooperate on issue jof access to water and the regulation of the flow of Sg Terengganu.

The Kenyir scheme is being upgraded as a cascading system with the construction of two dams – Puah (250 MW) and Tembat (15 MW) – geared towards maximising the use of water resources upstream. The Puah dam is 78-metre high with a crest length of 800 metres with a lake size of 6,979 ha. The Tembat dam is smaller in comparison with the height of 36.5 metre and the crest stretching 210 metres in length (Figure 4.4).

The two dams are located in the Tembat and Petuang Forest Reserves as part of its Hulu Terengganu Hydroelectric Project; this is an environmentally-sensitive area known for its large elephant population. In meeting the requirements of Detailed Environmental Impact Assessment (DEIA), TNB is taking measures to ensure that the hydropower development will have minimum impact on the habitat of the elephants and other smaller mammals as well as their movement and distribution. To do this, TNB Research Sdn. Bhd. (TNBR) in collaboration with the Department of Wildlife and National Parks (Jabatan PERHILITAN) and Universiti Kebangsaan Malaysia (UKM) are currently carrying out a study to monitor the elephants' movement during the construction as well as the operational stages. In the study, the elephants in the area are fitted with GPS satellite collars, from which signals are obtained, and their movements are tracked and monitored online. Results from the study will assist in the development of a human-elephant conflict management plan which will be used for the project as well.

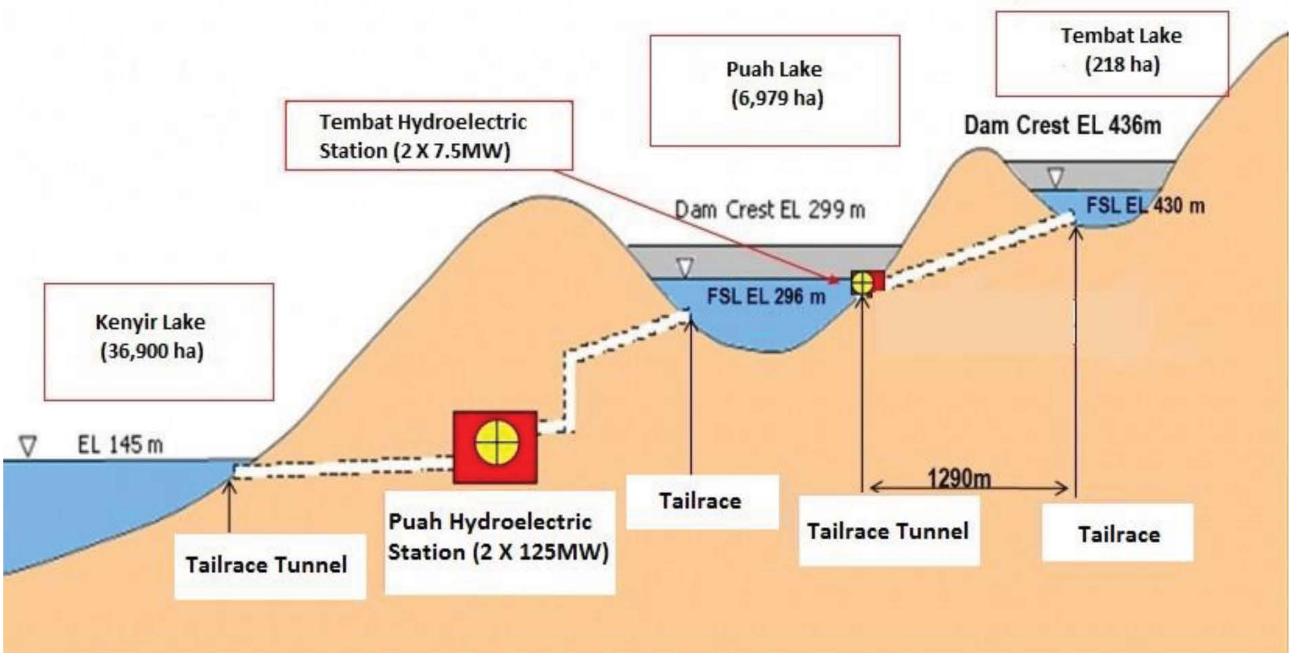



**Figure 4.4: Cross-section Illustration of Kenyir and Hulu Terengganu Hydropower Schemes**

### 4.5.3 Bakun Dam in Sarawak

Under the Sarawak Corridor of Renewable Energy (SCORE), the state government of Sarawak has in recent years announced plans to develop several large hydroelectric projects. The development spanned over a period of 22 years to generate 28,000 MW of electricity once fully developed. The power generated by SCORE's complete energy nexus would be used to fuel the industrial development of 70,709 km$^2$ of Sarawak's central region. The Sarawak Government is using this dam-induced industrialisation strategy as a prospect to attract significant Foreign Direct Investment (FDI) in an attempt to achieve the Malaysian Government's vision of Sarawak as a 'developed state' by 2020. Amongst the projects to be developed are the Baram dam (1200 MW), Baleh dam (950 MW) and Pelagus dam (770 MW) in the upper reaches of the Rejang River, Sarawak. In 2013 the 944 MW Murum dam was completed. The Bakun hydroelectric project, one Asia's largest dams outside China, involves the construction of a 207 m high rock filled with concrete dam creating a reservoir of 69,640 ha, about the size of Singapore. The cost for Bakun project was about US$ 4643 million (Sovacool and Bulan 2011).

The other nexus challenge for Bakun is encapsulated in the main criticisms from national and international bodies over the issue of the indigenous peoples (mostly Kayan, Kenyah, Lahanan, Kajang, Ukit and Penan ethnic groups) being resettled by the impoundment of the lake (Gabungan 1999; Choy 2005). Concerning ethnic composition among the resettlers, the Kenyah population was the largest group consisting of 5313 people, followed by the Kayan, 3995 people, with the balance comprised of 910 peoples (Andre 2012). The resettlement site, generally referred to as Kampung Asap is located approximately 40 km from the Bakun Dam site. Some people in some of the longhouses have also decided to move to other locations, not designated by the government. Most of the indigenous peoples involved were subsistence farmers for generations in a forest land of 107,000 ha with no previous participation in the Sarawak's economy. They also had a strong cultural attachment to the forest they left. Many studies claim that the communities' well-being as a whole was negatively affected. This was due to the fact that they have long depended on Sarawak's rivers and forests not only as a main source of livelihood but more importantly as their way of life. An ethnographic study by Choy (2005) found that the resettled communities had lost all four of the most important types of land: *temuda*, farmland around longhouses, *menoa*, land for game hunting and gathering, damp, cultivated land, and *oipulau*, or protected forest area. He concluded that ''the Sungai Asap resettlement area is environmentally unsuited to sustaining the social value and cultural identity of the indigenous communities affected by the Bakun Dam project'' (Choy, 2005: 66). To give a general sense of externalities associated with the major dams in Sarawak, Hartmann (2013) proposes simple criteria such as the numbers of hectares inundated per MW as environmental impact indicator and the number of resettled per MW as a measure of social impact. This is summarised as a spider diagram in Figure 4.5.

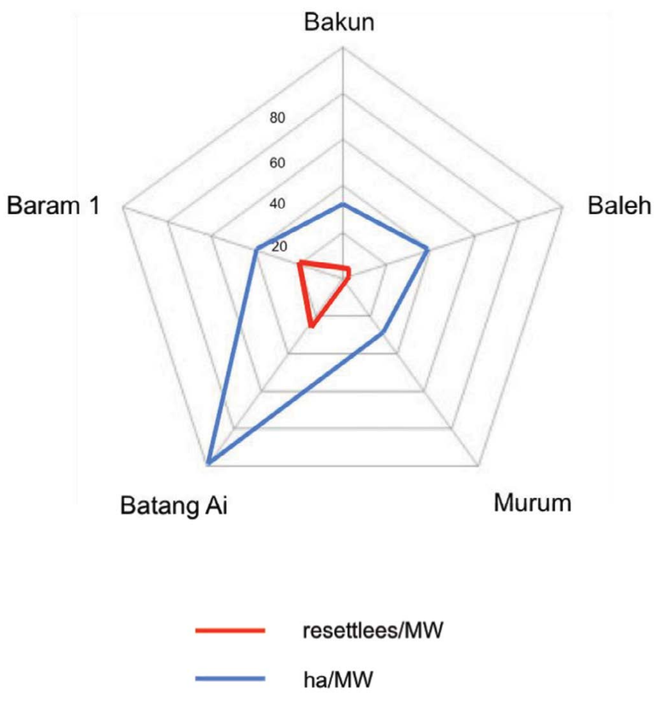



**Figure 4.5: Comparison of Relative Environmental and Social Impacts of the Major Dams in Sarawak**

**Source: Hartmann 2013.**

Bakun dam is managed by Sarawak Hidro Sdn Bhd, a wholly-owned company of the Minister of Finance Incorporated Malaysia. Its physical infrastructure was completed in 2010, and it began commercial operation in 2011. All the power generated is sold on a long-term agreement to state-owned Sarawak Energy Berhad (SEB). The distribution is undertaken by Sarawak Electricity Supply Corporation (SESCO), a subsidiary of SEB which in turn distributes electricity to consumers via its transmission lines. Sarawak Hidro would be earning around RM550 million from the average of 1000MW to 1,100MW of electricity it will be supplying to SEB in 2016. In return, it would be paying RM80 million to the State Government in royalty for the water it utilised (Sibon 2015). The question being asked about the overall dam-induced development strategy is whether there is enough demand for the electricity generated (Tick et al. 2011). Many energy-intensive industries involved in manganese processing, aluminum, and alloy smelting and polycrystalline silicone manufacturing have committed to investments in the Samalaju Industrial Park, but many good governance questions remain. Linkages with the local economy need strengthening, and the employment of foreign workers should be minimised to give way to job opportunities to the locals. The practice of subsidising the electricity tariff way below the market price to attract large-scale consumers to invest in Sarawak is also questionable. The issue of large excess undispatched capacity needs to be tackled strategically given the huge environmental footprint and social costs associated with these dams.

### 4.5.4 Cameron Highlands Dam in Pahang

There are two hydroelectric schemes cascading from the Peninsula's central mountain range. The Cameron Highlands-Batang Padang Hydroelectric Scheme includes seven power stations, five of which are mini hydro facilities such as Kampung Raja (0.8MW), Kuala Terla (0.5MW), Robinson Falls (0.9MW), Habu (5.5MW), and Odak (4.2MW). The other two power stations are high head underground schemes namely Sultan Yussuf Power Station or Jor (100MW) and Sultan Idris II or Woh (150MW) (Kun and Saman 2004). The cascading scheme uses water resources from the states of Pahang (Sg Telom and Sg Bertam), Perak (Sg Batang Padang and its tributaries) and Kelantan (diversion from Sg. Plau'ur) (TNB 1993). There are also three dams functioning as storage and flood control reservoirs:

- The Ringlet reservoir or Sultan Abu Bakar Dam is a lake about 3 kilometres long and up to half a kilometre wide, impounds the water from Sg Bertam and Sg Telom and provides a steady source of water for the Jor Power Station.
- The downstream Jor reservoir provides water for the Woh Power Station. It is created by two dams (main and saddle) which impound the water of Sg Batang Padang and the water discharged from the Jor Power Station.
- The earthfill-construction Mahang Dam is designed to regulate the flow of the water released from the Woh Power Station and to create a small head for the Odak Power Station mini-hydro.

The Ringlet reservoir was designed for a gross storage of 6.3 million $m^3$ with an active/live storage of 4.7 million $m^3$. However, it is currently badly silted with sediment accumulation estimated to have reached 5.0 million $m^3$ (Kun and Saman 2004). This situation means that the live storage of the dam had been reduced to less than 2.0 million $m^3$, compromising its capacity to regulate flood flow. Also, as the sediments accumulate in the Ringlet reservoir, the dam gradually loses its ability to store water to drive the hydroelectric turbines, reducing the lifespan of the dam which was designed to last for at least 80 years (Jansen et al. 2013).

Not only that soil erosion inundated the Ringlet reservoir with silt, but it also impacted flows of the river system including the Ringlet, Bertam, Habu and Telom rivers. The unregulated expansion of vegetable farming in Cameron Highlands, deforestation, and encroachment of settlements had caused land degradation on this important but sensitive water catchment ecosystem. Tenaga Nasional Berhad had spent over RM180 million over the past five years or RM40 million a year, cleaning up the Ringlet reservoir. However, the clean-up does not overcome the problem as the reservoir accumulates 500,000 cubic metres of sediment every year. The highland suffers from an unsustainable local decision-making with deleterious impacts on not only on water and energy security but also on human lives. Following a heavy rain on October 23, 2013, the water released from the Sultan Abu Bakar Dam had caused Sg Bertam to suddenly rise and breached its banks. In the aftermath, three died, and many houses and vehicles that were on the banks of the river or nearby were destroyed or suffered damage. The Cameron Highlands case presents three-at-a-time Nexus challenge whereby power generation is constrained by polluted water and agricultural expansion caused by unsustainable land use. Moving forward will require stronger law enforcement to ensure that farming activities and encroachment on river reserves do not compromise the function of the reservoirs on Cameron Highlands and elsewhere.

## 4.6 CONCLUSION

Increasing non-agricultural demands on water, growing food demands, and rapid urbanisation all place increasing pressure on water resources. This chapter shows that water resources play a vital role in not just the national economy, but also economic activities at the state level. Underpinning all aspects of development at the state level, water links together energy and food production. In some instances, as highlighted in the case of hydropower operation, upstream and downstream users often have conflicting needs. In the absence of water stress, like in some states, there is less competition for water and fewer trade-offs to be made. But this scenario does not necessarily mean there will not be any political trade-offs because water also holds great cultural and spiritual significance beyond physical and economic scarcity considerations. Also, high-level information uncertainty at the state level about water-energy-food linkages constrains the quest to frame appropriate strategies and policies. Finding solutions to secure water, energy and food resources will require significant action – technological and non-technological – both of which cannot be pursued independently.

# 5 SG PERAK BASIN

## 5.1 INTRODUCTION

Growing population, increasing the standard of living, energy demand for industrialisation, and food demand will put a lot of pressure on water resources. Pollution and contamination of available freshwater resources will further decrease available water. As the second largest river basin in the Peninsula, the Sg Perak basin is chosen as one of the case studies because it reflects all those challenges. More specifically, Sungai Perak has a series of hydroelectric dams that produce power for Peninsular Malaysia. Such competing demand invariably creates conflict between the upstream and downstream uses of river water resource.

## 5.2 THE RIVER BASIN

### 5.2.1 River System and Land Use

Sg Perak spans a length of about 427 km and covers a catchment area of 15,180 km$^2$, which is (almost) rectangular. The river begins its course from the mountainous Perak-Kelantan-Thailand border of the Royal Belum Forest Reserve in the North with elevations above 1,700 m above sea level. It flows Southward and subsequently discharging into the Straits of Malacca in Bagan Datoh. The major tributaries converging with Sg Perak at various points include Sg Rui, Sg Belum, Sg Temenggor, and Sg Piah at the upper basin and Sg Pelus, Sg Kinta and Sg Bidor at the lower basin (Figure 5.1). Sg Perak is also the second largest river system in Peninsular Malaysia. Within the river basin, there are seven administrative districts namely Hulu Perak, Kuala Kangsar, Kinta, Perak Tengah, Batang Padang, Manjung and Hilir Perak.

The Sg Perak Basin can be divided into three stretches categorised by its varying terrain and land cover. The lower stretches of Sg Perak consists of flat to gently undulating terrain and swampy areas except for isolated hills and ridges in the North-South direction of the Kg Gajah-Tanjung Tualang road. The second part lies between Parit and Chenderoh Dam. This region comprises of well-drained, moderately steep land which is largely under rubber tree crop. The catchment above Chenderoh is mountainous, and the river course is confined with little cultivation except for a small area around Gerik, and the region is mostly covered with forests.

The range of annual rainfall in the upper part of the basin is from 2400 to 3200 mm. Southwest to the Temenggor Dam the rainfall reduces between 1700 mm to 2200 mm. At the Southeast part of the basin, the average annual rainfall ranges between 2600 to 3400 mm. Of the 2,433 mean annual rainfall, 1,144 mm (47 percent) is returned to the atmosphere through evaporation, 1,119 mm (46 percent) appears as river runoff, and about 170 mm (7 percent) percolates as groundwater recharge.

The highest amount of rainfall generally occurs during March–April and October–November for the offseason and main season, respectively. The basin receives little rain from November to January. From May to July, the Southwest monsoon brings moderate rainfall to the basin. Between the monsoons from April to May and August to October, the basin has a peak in rainfall. Due to these climatic characteristics, there are two distinct rainy periods and a drought period (December to March).

The land-use of the Sg Perak Basin in 2010 is 9052 km$^2$ forest (59.63 percent), 4599 km$^2$ agriculture (30.3 percent), 1028 km$^2$ built-up (7.96 percent) and 321 km$^2$ (2.11 percent) water body (Figure 5.2). The basin is one of the largest cultivated basins in Peninsular Malaysia. The dominant plantation crops are oil palm (17.3 percent), rubber (8.8 percent), horticulture (1.8 percent), and paddy (1.4 percent). The projected

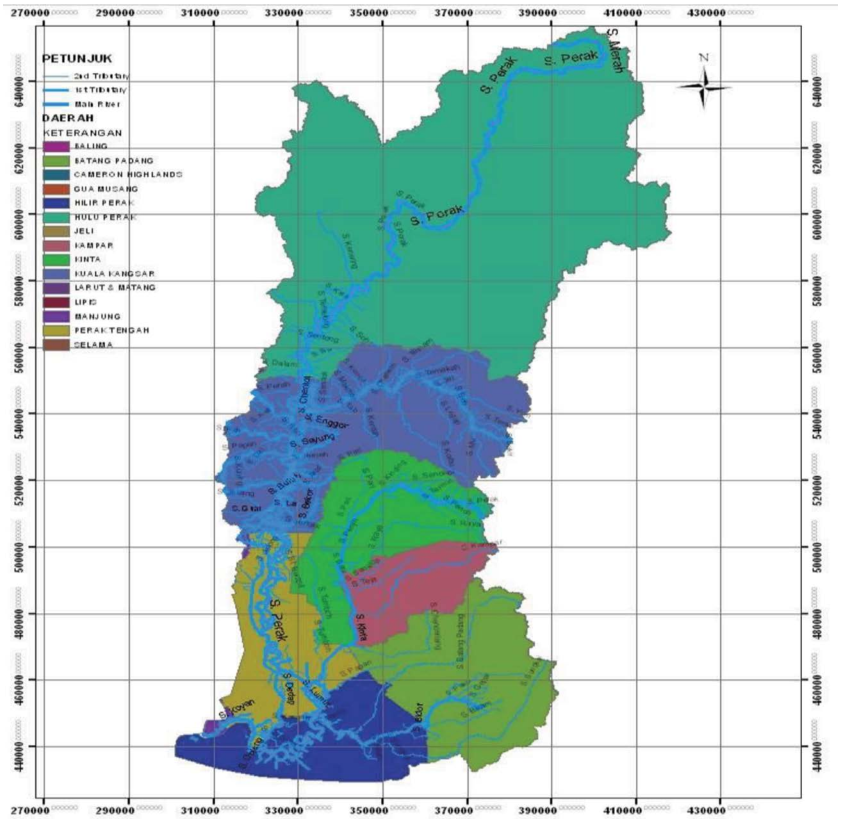



**Figure 5.1: Map of Sg Perak and its Tributaries.**

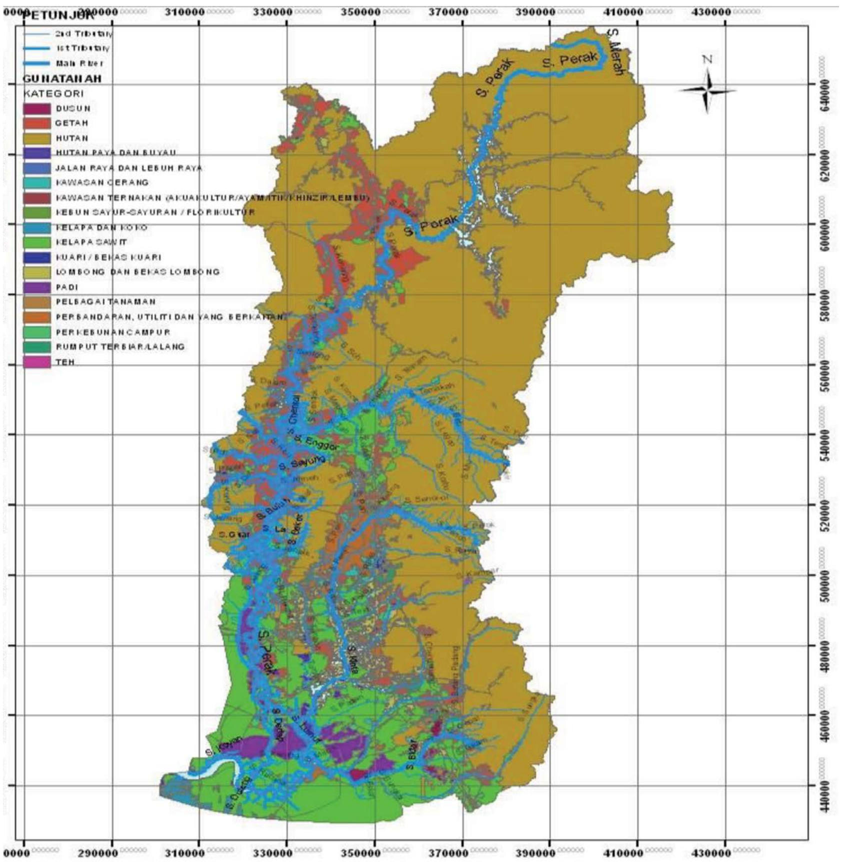



**Figure 5.2: Landuse in the Sg Perak Basin.**

Sg Perak basin population (excluding population in Manjong) in the year 2008 was 1,613,300. In the National Physical Plan, Sg Perak and Temenggor Dam are considered environmentally-sensitive areas (ESA) within the basin together with Banjaran Kledang-Salong-Bubu (highland category), Belum Forest Reserve, and Gua Tempurung (geological heritage category), to name a few examples (JPBD 2010).

## 5.3 WATER MANAGEMENT INFRASTRUCTURE

Sg Perak plays vital roles for the economic activities and ecosystem services in the state. On water availability, almost 70 percent of domestic water supply in Perak is sourced from Sg Perak. Apart from irrigation within the catchment, water from Sg Perak is also used for irrigation purposes in the Seberang Perak and Sg Manik Irrigation schemes. The management of water resources in Sg Perak basin is essential to meet the daily needs due to the increasing population growth and rapid economic development.

### 5.3.1 Rice Irrigation

Irrigation water for paddy cultivation constitutes the largest consumer of water in the Sg Perak basin. As of 2010, the total paddy irrigation demand amounted to 1,800 MLD (72 percent) compared to potable water demand at 713 MLD (28 percent).

There are two granary areas and seven mini granary schemes located in the Sg Perak basin. Seberang Perak or Trans-Perak Irrigation Scheme covers an irrigable area of about 8,529 ha with 4,900 families. Located in the Southwest of Perak state, the scheme has 330 km of canals, 316 km of drains and 443 km of farm roads. The scheme is managed by the Trans-Perak Project office. Located in the Southeastern part of Ipoh, the Sg Manik Irrigation scheme is also a double cropping zone covering an irrigable area of 6,318 ha involving 5000 families of farmers. Its infrastructure includes 227 km of canals, 200 km of drains and 187 km of farm roads. The scheme is managed by the Kerian-Sungai Manik IADA.

In addition to these two schemes, there are seven smaller granaries covering an area of 4,860 ha in the Sg Perak Basin. The two sizable mini granary schemes (covering an area of 4,108 ha), Changkat Jong (2,038 ha) and Trans-Perak Stage 1 (2,070 ha) are managed by JPS Perak. Irrigation water is extracted from Sg Perak along the right bank at the Kubang Haji and Bota pump houses.

The other five mini granary schemes are Beluru (180 ha), Bandang Lampar (100 ha), Kota Lama Kiri (112 ha), Saiong (180 ha), and Sumpitan (180 ha). JPS Perak also provides irrigation services to non-granary minor irrigation schemes with the Perak Tengah district such as Parit (186 ha), Senin (111 ha), Bota Lambor (754 ha), Kubang Haji (1,571 ha), Bota Kiri (500 ha), and Lambor Kiri (168 ha).

### 5.3.2 Hydropower Dams

The Sg Perak basin houses the Sg Perak Hydroelectric Power (HEP) scheme with a total installed capacity of about 1249MW. A series of human-made lakes have been created along the Sg Perak basin to cater for the construction of four hydropower dams in the upstream part namely Temengor, Bersia, Kenering and Chenderoh (Figure 5.3). They were completed and commissioned at different periods of time with Chenderoh being the earliest to be commissioned in 1926. These dams are used for the generation of hydroelectric power and also serve the function for flood control. The Temengor being the largest among the four dams has an average water level of 239 meter. The average depth of Chenderoh and Kenering reservoirs are 60.2 and 110 metre respectively. The combined catchment area of these four dams is 6,550 $km^2$ or 43 percent of the entire basin area.

### 5.3.3 Water Treatment Plants

Perak has two major water supply dams, 46 water treatment plants, 169 storage reservoirs, and 11,325 km of pipes (Table 5.1). The water supply management in Perak is divided into four regions namely North, South, West and East. Sg Perak basin covers 7 out of 10 districts in Perak while Sg Perak itself provides 40 percent of raw water for treatment by the Perak Water Board (Lembaga Air Perak, LAP). There are a total of 33 water treatment plants (WTPs)

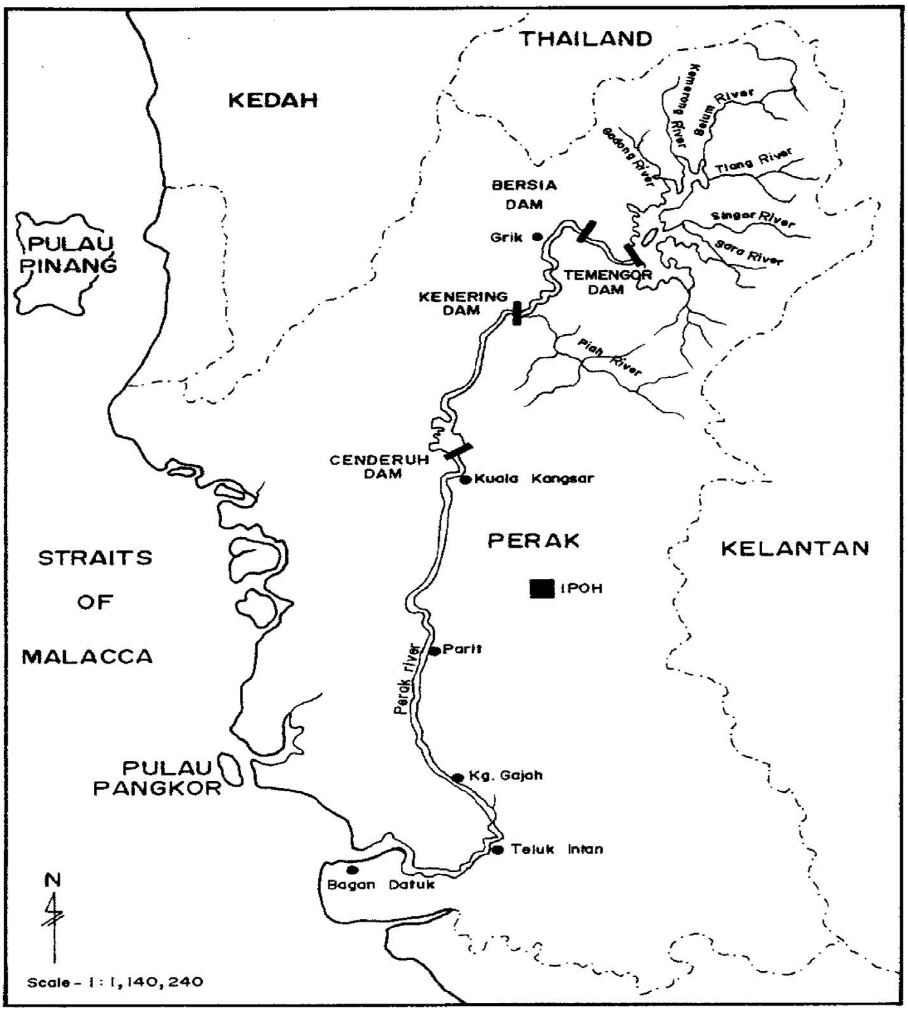



**Figure 5.3: Map indicating the location hydroelectric dams along Sg Perak.**

**Source: Ahyaudin 1996**

**Table 5.1: List of Existing WTPs along Perak River.**

| No | Water Treatment Plant | Water Source | Design Capacity (MLD) | Yield at Intake (by NWRS 2000) (MLD) |
|---|---|---|---|---|
| 1 | Gerik V | Sg. Kenderong/ Sg. Perak (Tasik Bersia) | 12.50 | 578.53 |
| 2 | Air Ganda | Sg. Perak | 0.22 | 12,155.02 |
| 3 | Pulau Banding Hydro Dam | Sg. Perak (Tasik Temenggor) | 2.27 | No info |
| 4 | Kota Lama Kiri | Sg. Perak | 22.73 | 4,564.52 |
| 5 | Sultan Idris II | Sg. Perak | 272.77 | 4,775 |
| 6 | Kg Teluk Kepayang | Sg. Perak | 136.0 | 4,903 |
| 7 | Kg. Paloh | Sg. Perak | 76.80 | 4,834 |
| 8 | Kg. Gajah | Sg. Perak | 4.32 | 4,996 |
| 9 | Bandar Baru Seri Iskandar | Sg. Perak | 34.13 | No info |
| Total | | | 561.74 | 36,806.07 |

**Source: Sungai Perak Integrated River Basin Management (IRBM) Study.**

in the Sg Perak basin with a total production capacity of 1358 MLD. Table 5.1 shows the list of WTPs that extract water directly from Sg Perak. In general, the water quality along Sg Perak falls within Class II levels. However, there is a threat from the increasing inputs from the more populated sub-basin of the Sg Kinta catchment. Majority of water treatment plants are using conventional water treatment system. Only a few water treatment plants (such as Sg Kinta WTP with its Dissolved Air Floatation technology) are using advanced technologies (such as Actiflo Clarification System, Ultra Membrane Filtration, and Ozone).

### 5.3.4 Wastewater Treatment Plants

There are 998 sewerage treatment plants (STPs) of mechanical (48 percent), oxidation pond and aerated lagoon (41 percent) and primary settlement (Imhoff/ septic tanks, 11 percent) technologies operating within Sg Perak Basin in 2010. All types of STPs are significant water pollution sources. This problem is not unique to Perak and applies to all states. Although Malaysia's sanitation coverage is exemplary, its rivers still suffer from the discharge of raw sewage from squatters, sullage of households, wet markets, and eateries, as well as from old and sub-standard wastewater treatment plants.

Sewage pollution is a major concern because it poses risks to human health since it contains ammoniacal nitrogen and many types of disease-causing organisms including *E-coli*. Sewage can also harm river ecosystems due to its rich nitrate and phosphate content which contribute to eutrophication. The regulation that governs sewage release into rivers – *Environmental Quality (Sewage) Regulations 2009* under the *Environmental Quality Act 1974* – is ineffective by design on two counts (Malaysia 1974). First, the 2009 Regulation is only applicable to any premises which discharge sewage with a population equivalent (PE) of more than 150. The government does not monitor and has no control over facilities with lower PE than 150 which discharges sewage into river systems. Secondly, the clause in the regulation allowing premises to contravene the standard in discharging their sewage (if a license to do so is granted by the Director-General of the Environment) in practice does not help to curtail river pollution.

### 5.3.5 Aquaculture

Aquaculture is a source of protein, employment, and income. Perak is Malaysia's largest freshwater and the second largest brackish/marine water aquaculture producer in 2008. In 2009, a total of 3,105 aquaculture farmers operated within the river basin. Freshwater culturists constitute 2,698 of the total with 55.1 percent involved in pond culture, while 10.1 percent use ex-mining pool, 2.9 percent use cage culture in rivers, pen (7.1 percent), cement tank (5.6 percent) and 9.6 percent are ornamental pond farmers. The Perak government in 2010 set the target to produce 200 metric tonnes (RM 1,480.0 million) of aquaculture products by 2015 from 137 metric tonnes (RM 950 million) production in 2010. While aquaculture is an important food production sector for the state, it is often perceived to be responsible for river water pollution.

## 5.4 WATER SECURITY CHALLENGES

The competition for scarce water resources is a reality in Perak. Industrial and domestic use is growing relative to that for agriculture. And water for electricity generation is rapidly increasing, too. The exclusivity of systems designed for agriculture is gradually breached to support other sectors.

### 5.4.1 Irrigation Water Demand

Irrigation has contributed to substantial increases in rice production productivity across Malaysia. As shown in Table 5.2, future irrigated water demand is expected to decrease with the improvement of irrigation efficiency. By the year 2050, the irrigation water demand is projected to reduce to 1216 MLD while the potable water demand increases to 1213 MLD. Due to low irrigation efficiency levels (50 percent at the year 2010), half of the irrigation water supply quantity is wasted. In addition to the competition with the other sectors, the availability of water for irrigation is becoming scarce due to climate

Table 5.2: Irrigation water demand projection for granary schemes in Sg Perak basin.

| Irrigation scheme | Projected Annual Irrigation Water Demand (m/c/m) | | | | |
|---|---|---|---|---|---|
| | 2010 | 2020 | 2030 | 2040 | 2050 |
| Seberang Perak | 308 | 280 | 237 | 220 | 206 |
| Sungai Manik | 209 | 190 | 161 | 149 | 140 |
| Mini granaries | 140 | 126 | 115 | 105 | 98 |
| Total | 657 | 596 | 513 | 474 | 444 |
| Total (MLD) | 1800 | 1633 | 1405 | 1299 | 1216 |

Source: NWRS 2010

change. The Malaysian Agricultural Research Institute (MARDI) has estimated that a 1°C increase in daily average temperature reduces 10 percent of the rice yield in peninsular Malaysia (Abdullah 2007).

### 5.4.2 River Pollution

Among the primary sources of pollution in Sg Perak are the urban runoff within the Ipoh City, industrial discharges from the industrial zones as well as from agricultural activities. The monitoring result by the Department of Environment in 2008 showed that the overall water quality status for Sg Perak was good falling within Class II levels (DOE 2008). The river water at the upstream at times reaches Class I levels but deteriorates as it flows downstream. However, Class III levels were detected in the highly urbanised Sg Kinta sub-catchment. It is anticipated that with future urbanisation in the basin, the water quality will be further compromised.

Total Suspended Solids (TSS) levels in Sg Perak basin can range from Class II to Class V, the latter resulting in river turbidity often caused by earthworks and land clearing activities. High turbidity, especially within the Sg Kinta basin, presents a problem for the raw water intake stations for potable water. In some cases 1,000 NTU (acceptable limit of turbidity set by Ministry of Health) reading may result in the shutdown of water treatment plants. High levels of TSS will affect the cost of treatment operations by clogging up pump systems, piping, filters and rapid filling of settling tanks. They also affect the aquatic life forms.

### 5.4.3 Sand Mining

Perak is confronting illegal sand mining activities. Up to May 2015, 110 cases of sand theft were recorded compared to 99 cases for the whole of 2014. Not only that sand theft impacted on sand revenue, but excessive sand dredging within the river channel also causes the degradation of rivers. This in-stream mining operation lowers the river bed level by incisions and deep down-cutting into the canal bottom, which in turn may lead to worsening bank collapse and erosion and endangers the structural integrity of the river banks.

In a study by JPS, river bed degradation was found at the Jambatan Iskandar station (Ministry of Natural Resources and Environment 2010). The probable river aggradation or degradation along Sg Perak was considered mild with less than 0.5 m throughout the 10-50 years data period. However, if the trends and scale of sand mining and theft continue, river bed degradation may see further worsening in the forthcoming years. There is an even greater need for the state to develop an effective environmental management tool for dredging to avoid further environmental deterioration.

### 5.4.4 Development Pressure

The catchment of Sg Perak is undergoing rapid development, and these give rise to numerous problems such as flooding, water quality degradation, riverbank erosion and encroachment of the river reserve. Within ten years the built-up areas in Sg Perak basin have increased by 917 $km^2$ or 315 percent. The Sg Kinta sub-basin with the Sg Perak basin recorded the highest growth. Because the Sg Perak basin covers a substantial percentage of the state, changing urban land use challenges to water resources, flood management, energy and water needs as well as higher pollution load.

## 5.5 WEF NEXUS

The Sg Perak basin is a showcase of how energy generation is competing with several other applications for water supply mainly paddy irrigation. This competition is interlinked and is already forming a policy nexus. Symptoms of conflict between the different types of uses are described below.

### 5.5.1 Water Supply and Thermal Energy

The water consumption demand from thermoelectric power is growing. In 2002, TNB Janamanjung or Sultan Azlan Shah Station started its operation to meet the anticipated growth in electricity demand in the Peninsula and help maintain the required power reserve margin. The plant delivers 2100MW of net power from three units of 700 MW generators. The plant runs on bituminous and sub-bituminous coal as fuel. It is also located 4.5 m above sea level, making coal imports easier. In 2015 a new unit utilising supercritical technology started its operation resulting in a total design capacity of 3100 MW.

The decision to place the station at its location off the Lekir coast in Manjung was based on its proximity to deep water (20 m). Such siting is a primary requirement for a coal-fired power plant, which requires voluminous seawater supply for cooling. The plant draws cooling water from the Straits of Malacca to condense the steam exhausted from the turbine and then discharge the water back into the same body of water.

However, the main demand for water within a thermoelectric power plant such as Janamanjung is for condensing steam. Thermoelectric power is generated by converting the energy in coal to steam and then uses the steam to drive a turbine-generator. After the steam is exhausted from the turbine, it is


**Photo 5.1: Sultan Azlan Shah Power Station, Manjung.**

Table 5.3: Water Consumption and Expenditure for Janamanjung Thermal Plant, 2011-2015.

| Year | Station Total Capacity (MW) | Water Consumption ($m^3$) | Annual Water Bill (RM) |
|---|---|---|---|
| 2011 | 2100 | 2,506,022 | 4,034,695.42 |
| 2012 | 2100 | 1,684,057 | 2,711,331.77 |
| 2013 | 2100 | 2,076,208 | 3,342,694.88 |
| 2014 | 2100 | 2,336,761 | 3,762,185.21 |
| 2015 | 3100 | na | na |

Source: Tenaga Nasional Berhad

condensed and recycled for use in the production of steam again.

For this purpose, Janamanjung station depends on the water supply from the Teluk Kepayang water treatment plant which is operated by *Lembaga Air Perak*. The four plants require clean treated water for their boilers (Table 5.3). In recent years water treatment plants, especially in Perak Tengah, increasingly have to process raw water with turbidity level exceeding 1000 NT. This high silt loading scenario has occasionally led to plant shutdowns to clean up the sedimentation. A worrying trend is observed when the Teluk Kepayang treatment plant is also facing the threat of shutdowns because of high silt load. In the event of extended shutdown hours, the operation of Sultan Azlan Shah power station might be interrupted. Given the centrality of this station to the national electricity grid, a severe pollution episode may trigger a national crisis of power supply failure.

## 5.5.2 Hydropower and Downstream Uses

Hydropower is often defined as renewable electrical energy since it harnesses the power of water by running the turbines and discharging it downstream. From a power grid operation perspective, hydropower is an excellent source of energy since the power output from a hydropower plant can be changed within fractions of a minute. The Sg Perak Hydro Scheme is a hydro-cascading system whereby water released from upstream dams is used to generate more electricity (Table 5.4).

The operation of a dam to avoid flooding is both


Photo 5.2: Kg Teluk Kepayang Water Treatment Plant.

**Table 5.4: Sungai Perak Hydropower Generating Capacity and Technology**

| Station | Make | | | Construction Period | Unit MW | No. of Units | Capital Cost (RM Mill.) | Total MW |
|---|---|---|---|---|---|---|---|---|
| | Turbine | Generator | Control System | | | | | |
| Temengor | Hitachi | Hitachi | Conventional Hardwired Relay Logic Control | 1974-1978 | 87 | 4 | 365 | 348 |
| Bersia | Hydroart | Siemens | | 1980-1983 | 24 | 3 | 153 | 72 |
| Kenering | Hydroart | Siemens | | 1980-1983 | 40 | 3 | 210 | 120 |
| Upper Piah | BHEL | BHEL | | 1989-1993 | 7.5 | 2 | 289 | 15 |
| Lower Piah | BHEL | BHEL | | 1989-1992 | 27.5 | 2 | | 55 |
| Chenderoh | Voest-Alpine | ELIN | SAT DCS | 1996-1999 | 10 + 8 | 3 + 1 | 63 | 38 |

challenging and risky. The risks for downstream flooding have to be weighed against the risk of lost income from the hydropower. One of the justifications for the construction of the Temengor dam was the realisation that the Chenderoh dam was no longer able to cope with flood response in the aftermath of the 1967 floods. In this context, Bersia is just a pass-through system since it cannot store a large volume of water because of its small size. Kenering dam on the other hand plays a more important flood regulating role while Chenderoh is often considered the last line of defense for flood control in the Sg Perak basin.

Power is proportional to the height of the water in the dam. Any lowering of the dam level will directly create a cost of lost generation. The dam operator will try to keep the dam level at the maximum level. Using the spillways to release water from the dam is a loss of income. There are two ways to release water; through natural river flow after generation, and through gates by discharging water using spillway. For the latter, in Temengor dam, water will automatically spill when it reaches 248.2m level. The minimum operating level for Temengor is 237 m (whereby only 2 out of 3 units can operate), but the critical level is 222 m. The lowest level ever recorded in the Temengor dam was during the El Nino year with the water level of 237.4 m.

Because it is important to strike a balance between development and resource protection, maintaining environmental or riparian flows is deemed important by the government. Hence the water discharge output from Chenderoh hydropower station must meet the requirement to ensure sufficient riparian flow. The process of maintaining the riparian flow begins with a start-up request by the National Load Dispatch Centre (NLDC) to connect and load the generator to or from the grid system to ensure Chenderoh station can generate the required energy while maintaining sufficient water discharge output. The current Standard Operating Procedures are as follows:

i. Operators shall monitor Chenderoh water discharge output and intake water level to ensure the water discharge output is sufficient as per government request.

ii. They shall advise the Despatcher of NLDC (DESP) on maintaining SJ Chenderoh water discharge by ensuring at least a certain amount of energy output is produced by running an equivalent number of units.

iii. If the running units are unable to meet the discharge output requirement, the operators shall advise DESP to start-up the Kenering unit. All units can be started and controlled remotely or locally where the operators shall decide which method is available and easiest.

iv. Finally, operators shall load up Chenderoh station to meet downstream riparian needs. All discharge output and spill gates operation will be communicated to *JPS*, *Pejabat Daerah Hulu Perak*, and *Pejabat Gerakan Balai Polis*.

With the completion of the TNB Janamanjung coal-fired power plant with its high capacity of 3,100 MW, the Perak Hydro-Power Scheme currently functions more as a backup system used for peak loading (on

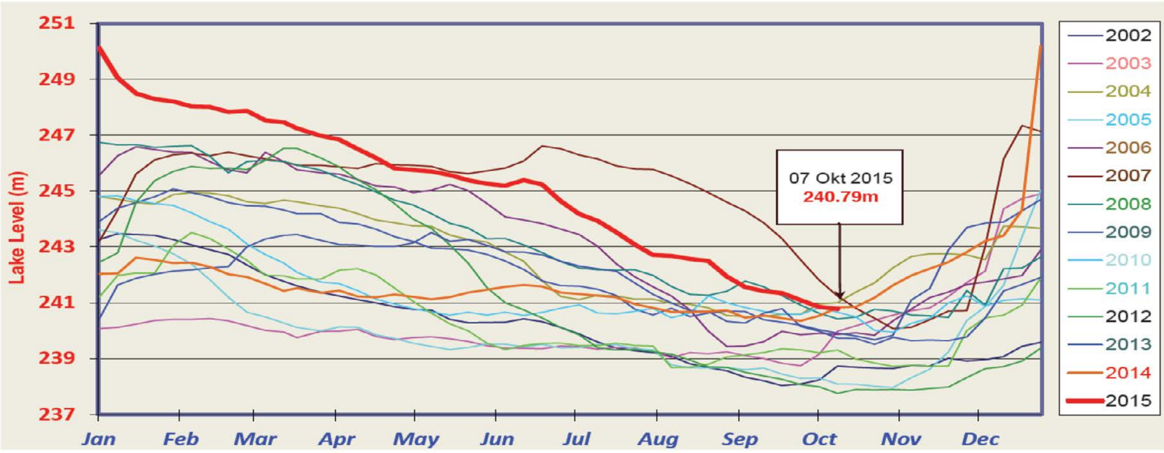
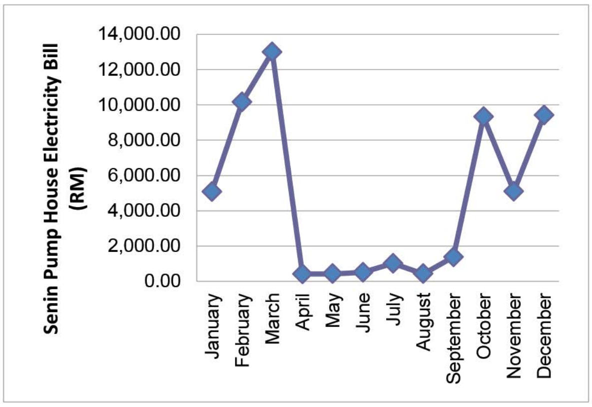


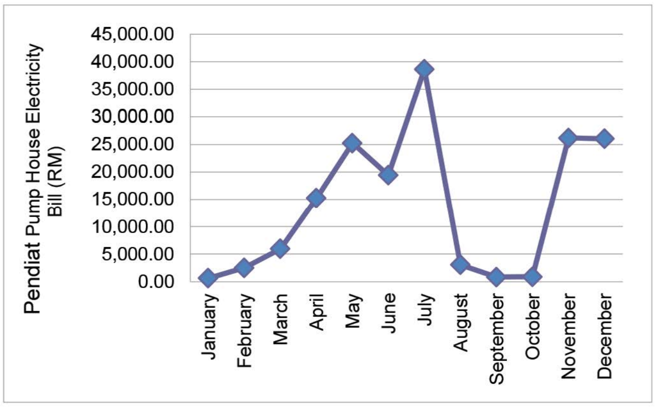

**Figure 5.4: Temengor Lake Water Level, 2002-2015**

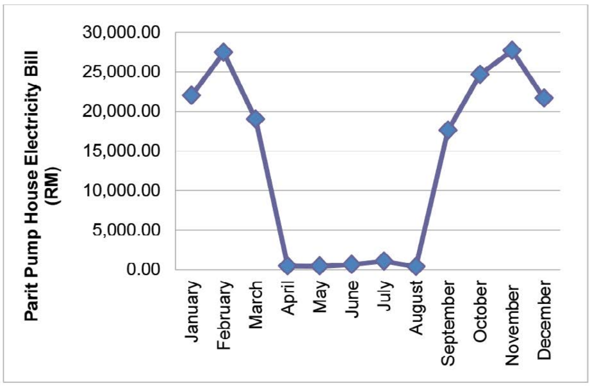
weekdays during office hours) rather than functioning as a baseload power source. Manjung power plants are also linked to the Bersia Group Control Centre to secure the information and control link. In the event of power failure, the dams in Sg Perak will back up electricity generation by the power plants in Manjung.

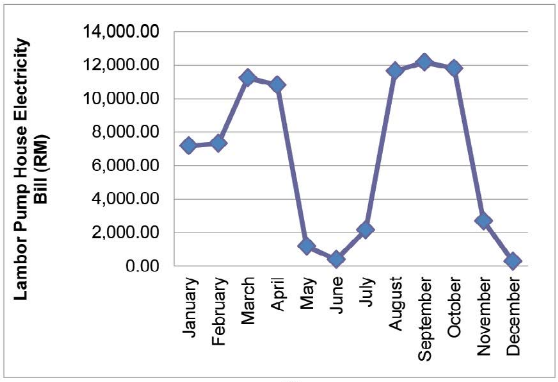
From the latest TNB data, the discharge at Chenderoh dam revolves around 200 $m^3/s$, which is theoretically sufficient for irrigation and other downstream uses. However, the real issue is the timing of the discharge. More often than not, both TNB and other users downstream would require water at the same time, leading to occasional upstream-downstream management conflict. This challenge sits at the centre of the nexus challenge of balancing the trade-off and finding synergies. As a peaking load system, TNB is left with the task of regulating the discharge of water when the Perak Hydropower Scheme is not generating electricity. The agreement between TNB and the state of Perak is silent on the issue of water resource regulation. In fact, the decision on water regulation is within the purview of TNB headquarters (under the single

**Photo 5.3: Damaged Spillway at Temengor Dam after 24 December 2014.**

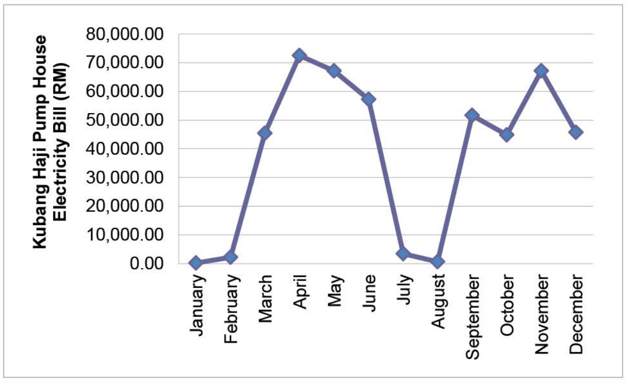


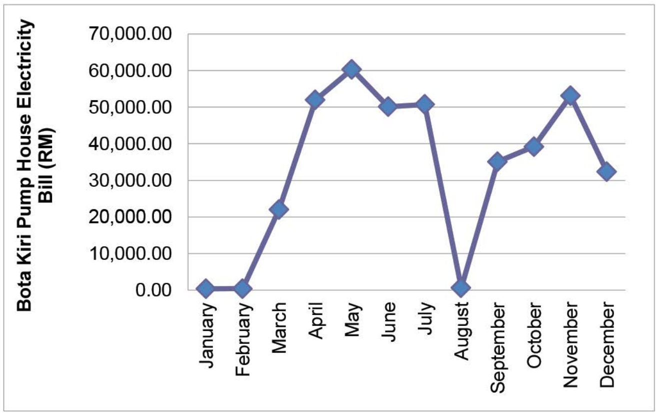




31



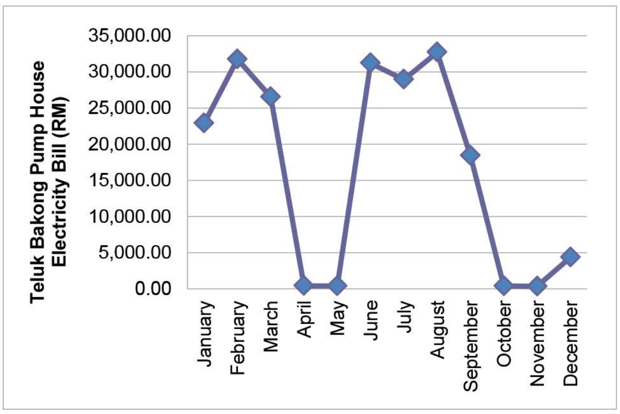




**Figure 5.5 Electricity Costs of Pump Houses in Perak Tengah**

*Water is essential for rice cultivation, and its supply in adequate quantity is vital. Off season requires more irrigation as the rainfall is less and the crop evapotranspiration is higher compared to the main season. The mid-season stage and the crop development stage are the most sensitive periods of water shortage. The decrease in irrigation supply within these two periods could lead to a sharp reduction in yield. In some cases within the Perak Tengah rice cultivation areas, low water level in Sg Perak will result in increased electricity expenditure to operate the pump houses.*

**Source: JPS Perak Tengah, 2014.**

buyer arrangement), whose priority is to ensure grid stability rather than detailing out the discharge of water at a river basin level. Considering the close relationship between water and energy, it is evident that the challenges stated above have to be dealt with in an integrated manner and single issues cannot be treated in isolation.

### 5.5.3 Energy for Water Pumping

The benefits of irrigation in enhanced paddy production are widely recognized. The yield of the mid- and small-size granary schemes within the Sg Perak basin has significantly increased since the construction of irrigation infrastructure in the 1970s to empower double cropping system. Schemes such as Trans-Perak and Sg Manik are mainly gravity-fed and therefore do not require pumping systems.

Be that as it may, with the onset of climate change and the changing river regime, a number of these irrigation schemes begin facing water stress conditions. Seberang Perak has been facing water supply crisis in the last two seasons with the water level. To irrigate Seberang Perak at the water level of 8.6 m, 21 $m^3$/s can be withdrawn through the Pokok Sena intake. Even for a gravity-fed system such as Trans-Perak, low water level means that irrigation water cannot be pushed to the end of the canals. This shortage demanded the use of mobile pumping which had caused the government a total of RM300,00 last year. For 2015 onwards RM400,000 has been requested from the government in anticipation of the same water stress scenario. At the Batang Padang intake, only 17 $m^3$/s was available for withdrawal. Occasionally some parts of Batang Padang will not receive water at all. The Ministry of Agriculture is planning to upgrade the Tronoh water storage to address this situation.

A series of pump houses in the Perak Tengah (non-granary) region are also operating under a sub-optimal condition with the low water level in Sg Perak. When the water level is low, mobile pumps have to be used to irrigate the areas. This had incurred higher energy cost to the government. Figure 5.5 shows the existing electricity cost for the seven pump houses managed by JPS Perak Tengah. This trend began some eight years ago but is now becoming more frequent. Under the Eleventh Malaysia Plan, 2016-2020, the government plans to upgrade the infrastructure for pumping to that the system can cope with lower water levels.

## 5.6 CONCLUSION

The lack of a link between energy and water authorities may mean that long-term energy sector development plans do not accurately assess water availability, resulting in unnecessary risks, inefficiencies or even conflicts. In the Sg Perak Basin, there is a conflicting interest between upstream water use for hydropower and downstream requirements for agriculture. To enable food productions all year around, downstream users expect the water flow at the Chenderoh gate to be maintained at 130 $m^3$/s throughout the year. Such a request is considered not feasible because the water level upstream of Temengor reservoir must be kept sufficient to avoid energy generation at a minimum water level.

The case of Sg Perak basin management represents a common challenge in the nexus of water-energy-food. What commonly stand in the way of more integrated planning and inter-sectoral coordination are the absence of agreements, the limited mandates of institutions, and shortcomings in decision-making processes, to name just three examples. A nexus solution may involve agriculture and power generation authorities negotiating a cheaper electricity to pump water or pumping water for agriculture at night when the hydro stations are not working. To optimise upstream and downstream water resources management, a new Standard Operating Procedure for regulating water-discharge is necessary, based on two considerations, timing, and technical justifications.

Timing is important since calculations and forecasts for water control including water estimated arrival time to each dam and local residents, water discharges for every unit and spill gates are made according to the cascading concept. Therefore it is suggested that TNB is informed early, guided by technical justifications of the flow rate needed, for cases of demands from other sectors such as releasing water downstream for local activities during draught season or restrict discharge during high downstream river level. This is to ensure that enough time is provided to reschedule loading for hydropower generation. For example, during drought season where the issue of water shortage arose, hydropower units will operate on minimum loading while the gate(s) at Chenderoh dam is opened to allow water to be discharged downstream.

Institutional responses that match the challenges faced in the basin is being developed. The state government of Perak is studying the possibility of establishing a water resources management agency. A new task force led by Town and Country Planning Department (JPBD) to monitor and manage development activities within the Sg Perak basin has been established. Among other things, it will use sections 19 and 20 of JPBD's Act 172 to regulate earthwork planning for physical development within the basin.

# 6 SG BERNAM BASIN

## 6.1 BACKGROUND

With the paradigm of IWRM gaining traction in public policy, the river basin scale has emerged in international discourses as the 'natural' scale for planning and managing water. This conceptual shift has challenged the hitherto widespread but misguided belief that water management is straightforward and can be handled by the 'water sector' alone. Specifically, most publications on scale framing have often highlighted the tension between ecosystems and administrative systems. The case study of Sg Bernam Basin is chosen to demonstrate the WEF nexus interaction in a shared river basin between the states of Perak and Selangor. The river provides water for irrigation to the Northwest Selangor granary whereby the rice fields form an important component of the landscape and economic life of the rural people. As a key rice-growing region, the sustainability of the basin is of strategic importance to the country. Therefore, all development activities within the basin especially its upper part must adhere to existing environmental guidelines by the state and federal governments. Often, trade-offs have to be made between these competing scales in governance processes to reach decisions that are mutually beneficial for water and land management that carry the interest of the nation and its people.

## 6.2 THE RIVER BASIN

### 6.2.1 River System and Land Use

Spanning a length of about 200 kilometres, Sungai Bernam is an inter-state river which drains the northern part of the Selangor state and the southern part of Perak state. The river begins its course from Gunung Liang in the Main Range in the East before traversing the middle part of the basin. This area is mostly agro-forest consisting of oil palms and rubber plantations before meeting the Straits of Malacca near Sabak Bernam (Figure 6.1). The major tributaries converging with Sg Bernam at various points include Sg Trolak, Sg Trolak, and Sg Slim. The Bernam river basin with its total area of 3,364km$^2$ is one of the four major river basins in the state of Selangor, the other three being the Selangor, Klang, and Langat river basins.

The average annual rainfall in the basin is about 1800 mm (JICA 1987). The highest amount of rainfall typically occurs during March–April and October–November for the offseason and main season, respectively.

The forest land use in upper Bernam Basin decreased from 689.2 km$^2$ in 1984 to 536 km$^2$ in 2004. The dwindling of the forest land use is associated with land clearing activities for oil palm agriculture and the development of new township of Proton City and Bernam Jaya as well as other housing estates within the Batang Padang District in Perak. Agricultural land for oil palm cultivation increased, but the rubber land use decreased (Mohd Suhaily et al. 2008).

With a small population and minimum presence of industries, the land-use for the mid part of the Sg Bernam Basin is dedicated mainly for oil palm crop plantation. Water resource from Sg Bernam is primarily channeled for rice irrigation (Figure 6.2).

### 6.2.2 Rice Granary and Water Use

Malaysia's fourth largest granary, the Barat Laut Selangor Rice Irrigation Scheme (also referred to as Tanjung Karang) covers an irrigable area of about 18,195 ha is located within the Sg Bernam basin. The project area is located on a flat coastal plain in the Integrated Agricultural Development Area (IADA) which sits in the district of Kuala Selangor, and Sabak Bernam at latitude 3°3500 N and longitude 101°0500 E. There are approximately 10,300 paddy farming families who reside within the IADA who are involved in rice production. IADA Barat Laut

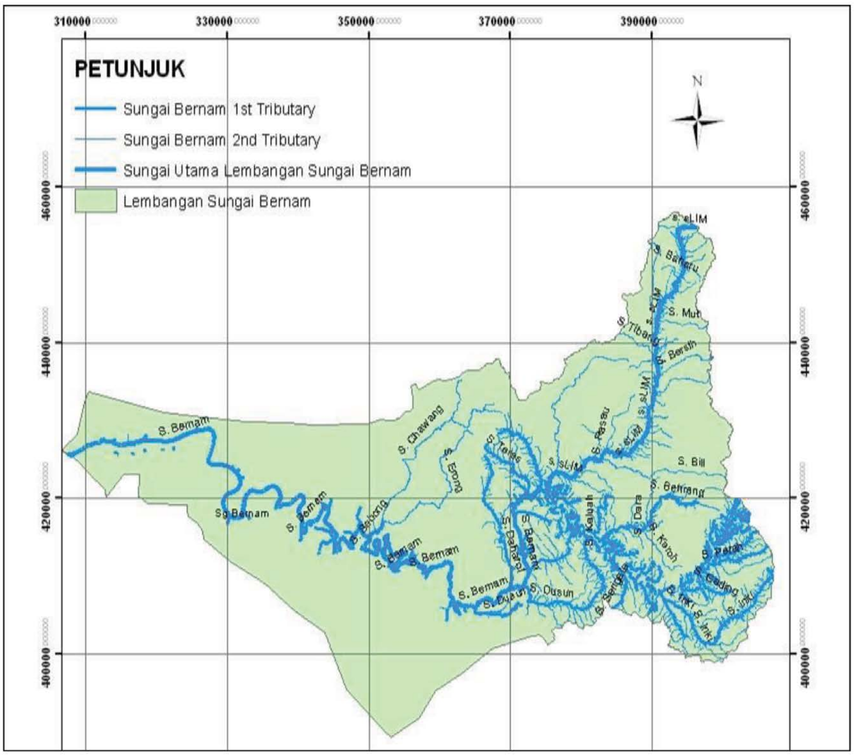



Figure 6.1: Map of Sg Bernam and its Tributaries.

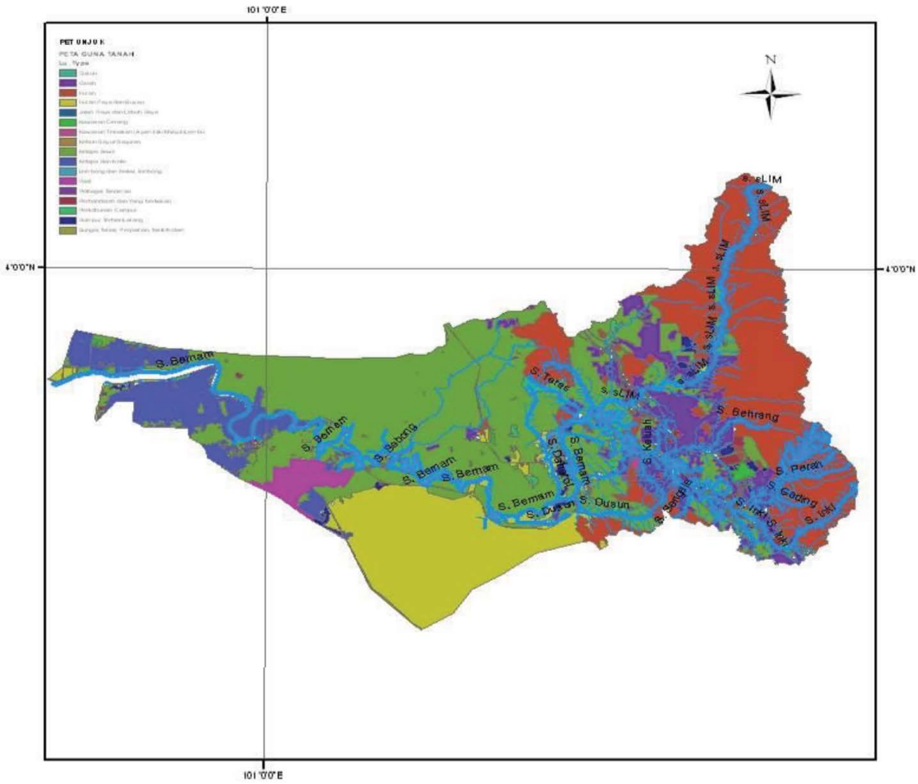



Figure 6.2: Land use in in the Sg Bernam Basin.

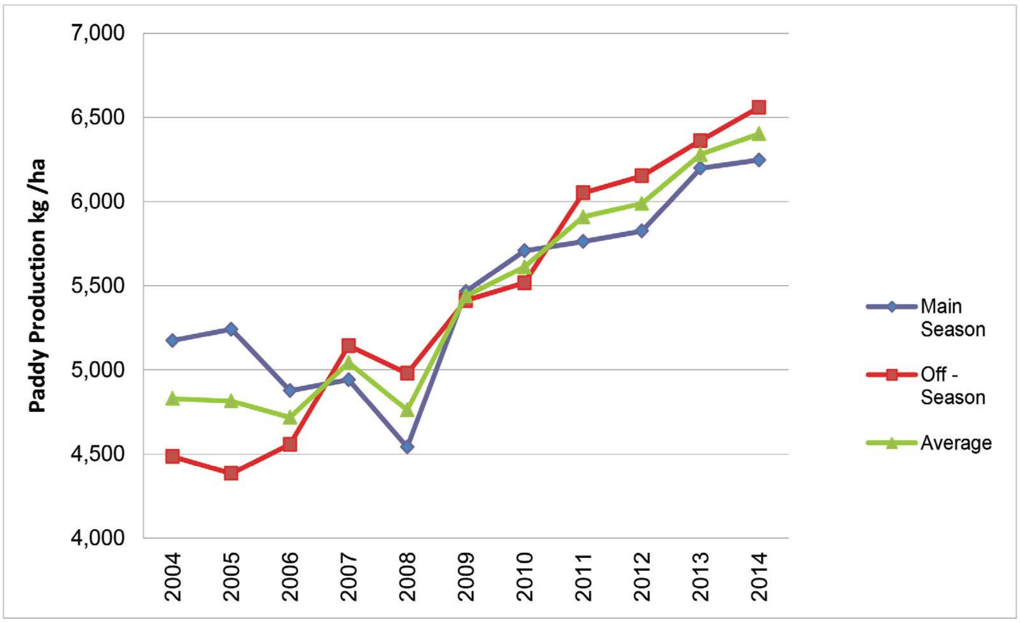



**Figure 6.3: Seasonal Average Paddy Production for the Year**

**Source: Integrated Agriculture Development Area (IADA) Barat Laut Selangor**

covers an area of almost 100,000 ha. In addition to rice cultivation, there is 55,000 ha of land dedicated for palm oil, 20,000 ha for coconut and 5000 ha for fruits and vegetables. Around 9,119 paddy farmers are working in this agricultural zone. In 2014 the yield for IADA was 234,272 metric tonne (double season), and the average yield was 6.403 mt/ha (Figure 6.3). The average net income of farmers was RM3,200 per month in 2014.

The irrigation scheme extends in a Northwest-Southwest direction over a length of 40 km along the coast with a width of 5 km average. The main irrigation and drainage canals run parallel with the coast. The bulk of the irrigation supply is diverted from the Bernam River Headworks (BRH), located about 130 km upstream of Sg Bernam estuary. The Bagan Terap pump house, situated further downstream of BRH or about 62 km upstream of the river mouth, augments the supply. The 14.5 km long Feeder Canal from BRH flows through Sungai Karang (peat swamp) forest reserve on the right bank and Raja Musa forest reserve on the left bank before adjoining into Sg Tengi (24.5 km) and then flows in the Main Canal in the irrigation scheme. The width of the Feeder Canal is 50 m with the maximum depth of 3.5 m.

**Photo 6.1: Bernam River Headworks**

Traditionally rice is grown under continuous submergence or intermittent or variable ponding conditions depending on the farmer’s choice and also on the water resources. Rice is grown two times in a year mainly from August to January (main/wet season) and February to July (off/dry season). With irrigation, the area records the highest yield of cleaned paddy (6198 kg/ha in 2012/13)(Table 6.1).

**Table 6.1: Time Series Data- Planted Area, Average Yield of Cleaned Paddy and Paddy Production for Granary Area, IADA Barat Laut Selangor for the Year 2003-2013**

| Year | Planted Area (Hectare) | Average Yield of Cleaned Paddy (kg/hectare) | Paddy Production (Metric Tonne) |
|---|---|---|---|
| 2003 | 37,148 | 5,380 | 199,873 |
| 2004 | 37,233 | 4,829 | 179,805 |
| 2005 | 36,518 | 4,814 | 175,784 |
| 2006 | 36,754 | 4,717 | 173,376 |
| 2007 | 36,516 | 5,042 | 184,115 |
| 2008 | 36,602 | 4,761 | 174,247 |
| 2009 | 37,258 | 5,439 | 202,633 |
| 2010 | 37,472 | 5,612 | 210,292 |
| 2011 | 37,460 | 5,908 | 221,295 |
| 2012 | 37,835 | 5,989 | 226,580 |
| 2013 | 37,833 | 12,560 | 237,598 |

### 6.2.3 Inter-State River Governance

The stakeholders of the Sg Bernam basin share many challenges in managing this transboundary river basin, including:

- Sand mining regulation – the two states operate different criteria in managing sand resource leading to deleterious environmental impacts.
- River reserve and catchment area – inconsistent gazettement status in the two states lead to poor maintenance of the river and its tributaries as well as encroachment in the river reserve by agricultural activities.
- Uncontrolled development – land clearance from development activities and quarrying from both states leading to sediment loading in Sg Bernam.

The water authorities both in Selangor and Perak states are currently negotiating a new set of measures to better govern the inter-state river. Among the instruments suggested is the publication of the State of the River Report as an informational strategy apart from strengthening the capacity of law enforcement.

## 6.3 WATER SECURITY

Seventy-five percent of the available water resources in Malaysia are used for rice irrigation. The Sg Bernam Basin is an important granary which is dependent on continuous water security.

### 6.3.1 Irrigation Infrastructure

The Bernam River is the only source of the irrigation supply diverted by Bernam River Headwork (BRH, started operating in 1964) into the feeder canal (Photo 6.2). Then water is conveyed into Tengi River and thence to the intake point of the main canal at Tengi River Headwork (TRH). The distance between BRH and TRH is about 36 km. The design discharge at the BRH at the elevation of full supply level (FSL) of 9.6 m is 30.6 $m^3/s$ . The average annual rainfall is about 1,800 mm (DID and JICA 1998).

Irrigation water is delivered directly from the main canal to tertiary canals through Constant Head Orifices (CHO) offtake structures. Tertiary canals are spaced 400 m apart along the main canal. A standard irrigation block (rectangular shape with red border) has a net command area of about 150–200 ha. Few irrigation blocks are of small sizes at the tail end of the tertiary canals. There are three to five irrigation

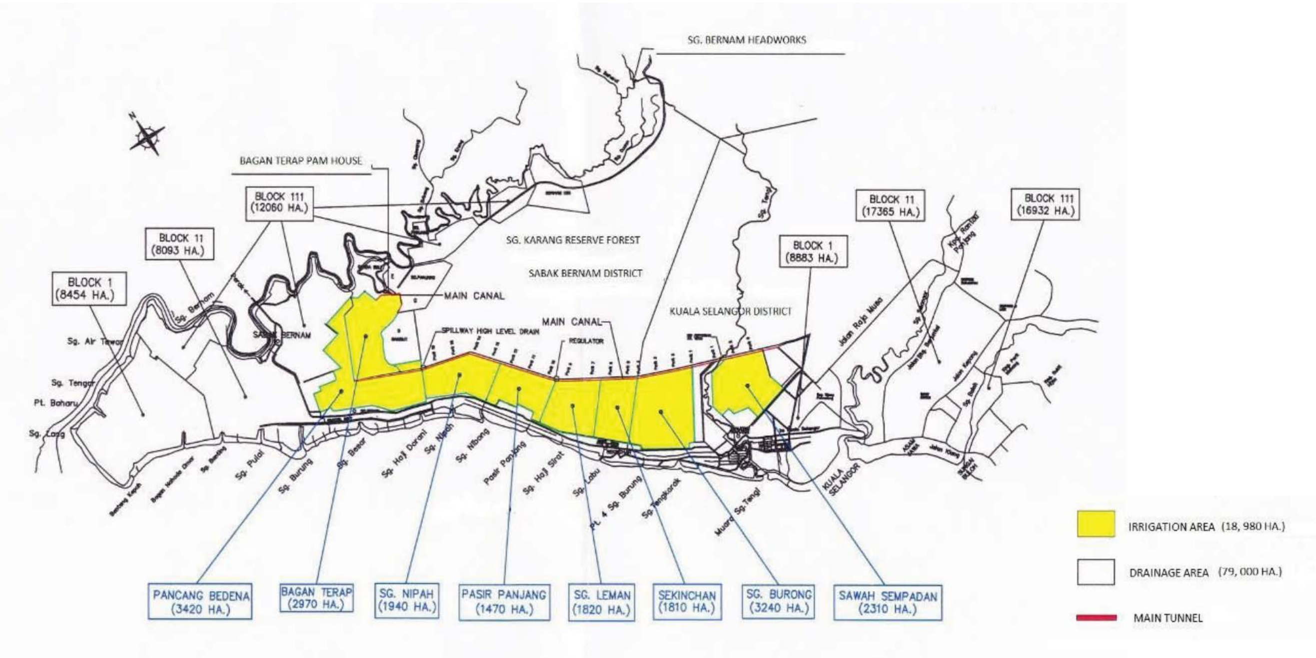



**Photo 6.2: IADA Barat Laut Project Plan**

blocks that receive irrigation water in their paddy plots direct from two tertiary canals.

Water supplies reach the fields through a network of canals. The tertiary canal is the basic unit as it is the last point of control in the main irrigation system. The irrigation supply into each tertiary needs to be decided based on the estimated crop water demands. The demands depended on soil, weather, crop conditions and targeted irrigated areas. The irrigation demand estimation for each tertiary canal is therefore independent of the others. A pump house was constructed in 1962 on the lower reaches of the Bernam River at Bagan Terap to provide the water supply for the northern portion of the area approximately 1,000 ha.

### 6.3.2 Water Treatment Plant

The 2014 total treatment plant capacity in the country is 18,730 million litres per day (MLD) which has grown from 346 MLD in 1959, representing an average of 319 MLD annual increase in the last 42 years. This production capacity is sufficient to meet the current demand of 15,790 MLD (Malaysian Water Association 2015).

Public water supply in Selangor was first provided by its Public Works Department in 1896. The first water supply scheme was the Ampang Impounding with a capacity of 1.5 MLD. By 1999, Selangor and Kuala Lumpur altogether had 31 water treatment plants, five major water supply dams, 320 pump houses, 275 service reservoirs, and more than 13,000 km of pipes.

The operating cost of the water treatment plant is tied to the efficiency of the plant, which is governed by the consumption of electricity, chemical and filter backwash water apart from plant operating personnel.

In 2013, Puncak Niaga Sdn Bhd was given the license for the abstraction of river water from Bernam River Headworks to supply 65 million litres of water daily to the population in Sabak Bernam. In 2015, the installation of a booster pump at the Bernam River Headworks treatment plant to increase the capacity of treated water to 25 million litres daily. According to Puncak Niaga's annual report, 19 million metric tonnes of raw water was drawn from the Bernam river in 2013. Although public supply withdrawals are returned to the system and available for other uses, discharge is treated (requiring energy) before it is released back into surface water systems.

### 6.3.3 Issues and Challenges

The water security of Sg Bernam river basin is threatened by increasing demand for rice irrigation, river pollution, low irrigation efficiency partly due to wastage by farmers, climate change, and the increasing pressure from development activities arising from the northern part of the basin.

#### *Water demand*

The irrigation demand for this granary area is increasing from 2010 to 2050 as illustrated in Table 6.2. In the past conventional management of the river basin has focused on infrastructure solutions to increase the supply of water resources. To avert conflicts during drought events – especially now with Malaysia aiming for national self-sufficiency in rice production – demand-side management and nature-based solutions should be explored by all stakeholders.

#### *Irrigation efficiency*

Increased efficiency in the use of water is essential for future food security in Malaysia. The overall irrigation efficiency of rice-based systems is less than 50 percent and is lower in the wet than in the dry season. Irrigation management for rice irrigation is difficult because of different planting schedules, variability in soil and crop conditions and unreliable intake of water in the main canal due to the absence of storage reservoir and their uneven distribution to tertiary canals.

#### *River pollution and sedimentation*

As in many parts of Malaysia, water treatment plants have to be closed occasionally or permanently due to deteriorated raw water quality. In 2014, the contamination of diesel oil at the water treatment plant at the Bernam River Headwork had caused a total of 30,831 homes in parts of Sabak Bernam and Hulu Selangor to experience water supply disruption.

According to data from streamflow stations along Sg Bernam, the mean sediment loading near Tanjung Malim is estimated at 450 ton/km$^2$/year, a figure higher than the loading observed in the 1990s. The mean sediment load consistently increased from 1.0 ton/km2/year to some 6.0 ton/km$^2$/year.

At further the downstream of Sg Bernam, the mean sediment load drops some 30 percent perhaps due to some actions of temporary instream storage in between these two streamflow stations

#### *Climate change*

In addition to the competition with the other sectors, the availability of water for irrigation is becoming scarce due to climate change. The Malaysian Agricultural Research Institute (MARDI) has estimated that a 1°C increase in daily average temperature reduces 10 percent of the rice yield in peninsular Malaysia (Abdullah 2007).

A modeling study of water demand availability by NAHRIM found that there will be eight months of water deficit (3 percent) under climate change scenarios and 22 months deficit (9 percent) for the climate scenario of 1 in a five year condition (Figure 6.4). The water deficit is expected to be more frequent for the second 10-year period of 2041-2050, especially for January and March. The largest deficit is in January 2048 at -27 MCM/month (demand 28.5 MCM/month). This water deficit is due to the lower future river flow and hence lower availability at BRH intake point at Sg Bernam.

A study by Masud and colleagues (2015) estimated the willingness to pay (WTP) among paddy farmers (N=385) for a planned adaptation programme for addressing climate issues in the IADA Barat Laut agricultural zone. This study found that the majority of the respondents (74 percent) were willing to pay to address climate change issues in their area. Climate change impacts on agricultural production were cited as the most important motivating factor for their willingness to pay while avoiding future natural disasters was ranked second most important reason.

#### *Development pressure*

Demand for water from housing water supply is expected to increase with population and economic growth in the upstream of Bernam basin. The analysis of the land use change patterns from 1984

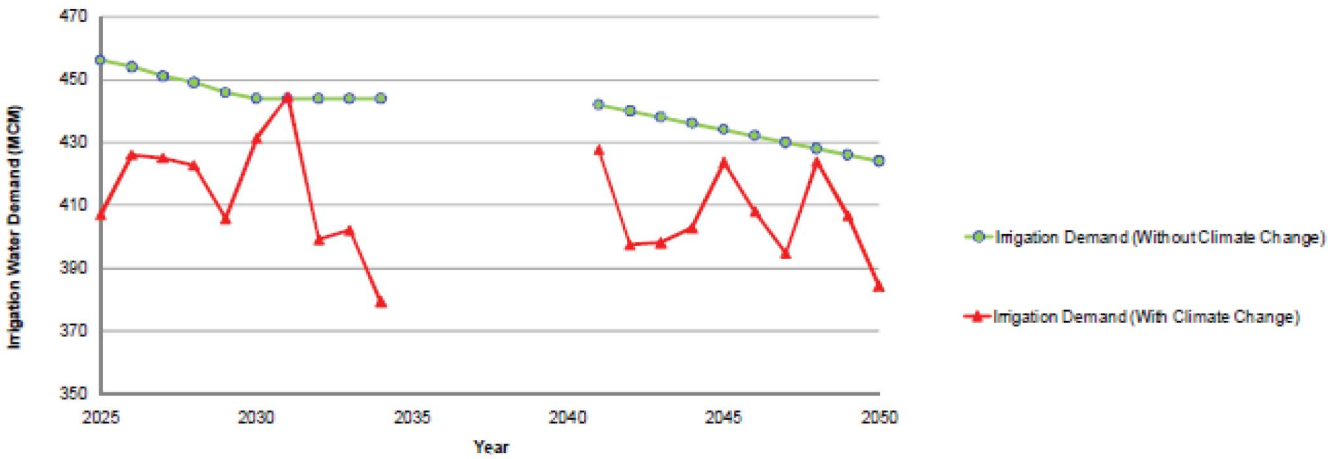



**Figure 6.4: Irrigation Water Demand Projected for IADA Barat Laut Irrigation Area.**

**Source: Zainab, 2007**

to 2000 (Mohd Suhaily and Reid 2010) shows that the upper Bernam Basin has been experiencing rapid development in the past. This pattern of growth is at present continuing, posing further uncertainty on water security for irrigation in the years to come.

## 6.4 WEF NEXUS

Water security has two components— quantity and quality—both influencing its interactions with food production and energy. Water scarcity, in particular, is the proximate cause of competition in the water–food–energy security arena.

### 6.4.1 Water for Food Production

Irrigated agriculture is by far the largest consumptive user of water in many developing countries like Malaysia. Water and food are thus tied to one another fundamentally. On top of their physical relationship, economic systems intervene, whether through pricing schemes, politics, technology or shifting patterns of consumption.

The total water requirement for rice production is about 1,000–1,500 mm depending on the variability among schemes. In Tanjung Karang Irrigation Scheme, double cropping is practiced in a year. This system demands plenty of water in the scheme. The water requirement for pre-saturation is theoretically 150–200 mm, but can be as high as 650–900 mm when its duration is long (24–48 days; De Datta 1981; Bhuiyan et al. 1995). An enormous amount of water is supplied to inundate fields for pre-saturation before planting of the crop. Only a small fraction of this water is consumed at its initial stage of growth.

The management of large canal irrigation systems like the Tanjung Karang Rice Irrigation Scheme in Malaysia is a complex. Poor and uneven water distribution is the bottleneck for improving water management in many of these schemes. Most irrigation systems in developing countries are criticised for inefficient use of water resulting in either over or under irrigation. The Tanjung Karang Rice Irrigation Scheme is not an exception. The scheme also has the reputation of having low irrigation efficiency. In irrigation distribution, tertiary canals located at upper reaches of the main canal normally get more water than in the downstream due to uncontrolled gate opening of the Constant Head Orifice (CHO) offtake structures. Many downstream farmers often could not get irrigation water, especially during the dry season. At times this situation leads to conflicts among farmers and the authorities.

In irrigation scheduling program, the amount of potentially available discharges for irrigation supply and actual water demand on actual planting schedules is yet unknown. Pre-designed irrigation scheduling is usually followed based on experience and knowledge of previous irrigation seasons. Due to this, an uneven allocation may occur, and

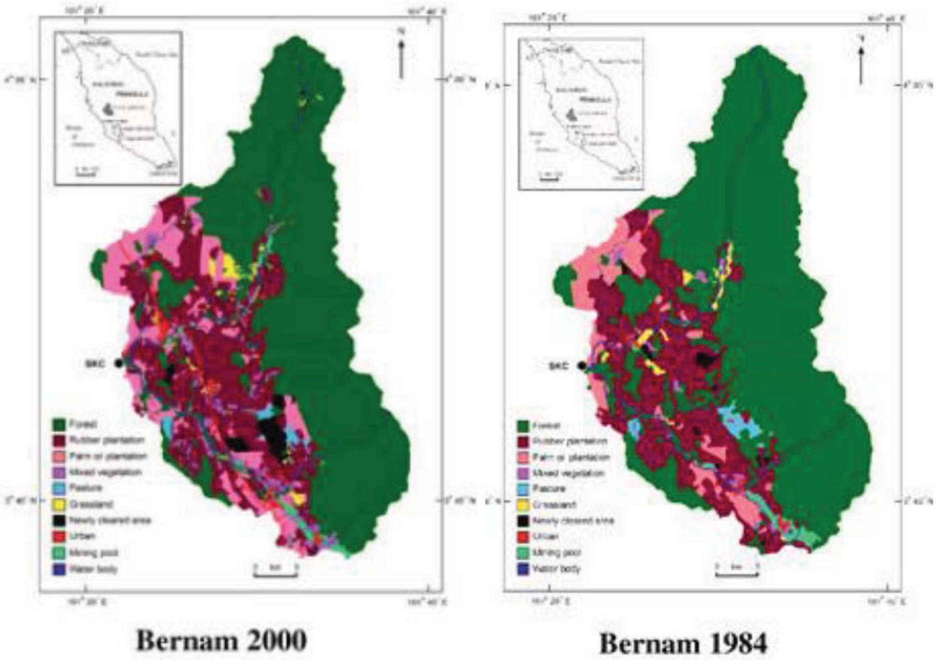



**Figure 6.5: Development in the Upper Sg Bernam Basin, 1984 and 2000.**

**Source: Mohd Suhaily and Reid, 2010**

shortage against drought failed to be overcome as this particular scheme has no storage reservoir. Therefore, it is important to match the water supply between the system head and the trade-off water use for the actual field conditions so that distributaries will receive an adequate supply for their service areas. The maintenance of the irrigation system is becoming increasingly expensive due to rubbish trapped in the canals, eutrophication, abuse or vandalism of irrigation infrastructure and so forth.

### 6.4.2 Energy for Food Production

The development of modern agriculture is closely related to the increased use of energy. Water provision in IADA Barat Laut mainly gravity-fed, but previously not evenly distributed. A pump house was constructed in 1962 on the lower reaches of the Bernam River at Bagan Terap, 63 km upstream from the estuary of Sg Bernam, to provide the water supply for the northern portion of the area approximately 1459 $km^2$. With this infrastructure, energy is used for pumping irrigated water. By the 1980s the pumping capacity of the Bagan Terap pump house has decreased to 70 percent of its designed capacity. In recent years, the diesel pumping system was changed to electricity-operated four pumps with three operating at once with the capacity of 1.8 $m^3/s$. The electricity bill is RM25,000 per month for April, May, June and October, November, December, that is the planting season. There are many operational challenges associated with the pump house:

- Suspended sediment load of 3,500 to 5,000 mg/lit during high tide and 1,100 mg/lit during low tide, affecting the impeller
- Silts accumulation at the intake channel and irrigation canal
- Desilting cost
- Intrusion of saltwater

Reusing water and adopting conservation measures could help Malaysia to cut its water demand by more than half. IADA also uses 14 pump houses to recycle irrigated water to the rice fields in Panchang Bedena and Bagan Terap (Table 6.3). The capacity for the Phase 1 single-unit pumps is ten cusec whereas Phase 2 uses twin-unit pumps with the capacity of 5 cusecs. Among the challenges faced in using these pumping systems include:

**Table 6.2: Electricity Usage for Recyclable Water Pump House at Panchang Bedena and Bagan Terap Irrigation Area**

| No | Location | Total (RM) | |
|---|---|---|---|
| | | 2013 | 2015 |
| 1 | West Parit 1 | 2,851.50 | 7.65 |
| 2 | West Parit 3 | 47.24 | 22.75 |
| 3 | West Parit 8 | 392.70 | 7.15 |
| 4 | East Parit 1 | 918.50 | 7.65 |
| 5 | East Parit 3 | 107.50 | 139.10 |
| 6 | East Parit 5 | 14.85 | 4.75 |
| 7 | East Parit 7 | 14.85 | 7.15 |
| 8 | East Parit 9 | 14.80 | 364.70 |
| 9 | East Parit 11 | 62.15 | 8.15 |
| 10 | East Parit 12 | 1,661.57 | 7.15 |
| 11 | Sg. Hj. Dorani Parit 1 | 14.80 | 7.15 |
| 12 | Sg. Hj. Dorani Parit 3 | 6.15 | - |
| 13 | Sg. Hj. Dorani Parit 4 | 14.80 | 2.15 |
| 14 | Sg. Hj. Dorani Parit 11 | 941.25 | 142.25 |
| Total Electricity Usage per Season | | 7,062.66 | 727.75 |

- Pump inverters often breaks down due to low voltage, common fault, etc
- Irregular maintenance of the pumps especially their motor
- Operation by farmers not following the schedule set by IADA

Besides, areas surrounding the pumping houses are not adequately maintained for instance with damaged net trapping floating rubbish accumulating around the pumps. Since the maintenance requires skilled workers, the costs are often very high.

## 6.5 CONCLUSION

Water resources are limited, and effectiveness of use is determined by technology and management. But water use trends cannot easily be altered as water demand is determined by demography and consumption behaviour. Using a nexus approach to steward water resources sustainably in energy supply chains and food supply chains is seen as a promising approach. The institutional gaps in dealing with nexus challenges in the Sg Bernam Basin is summarised in Figure 6.6.

**Photo 6.3: Bagan Terap Pumping Station.**

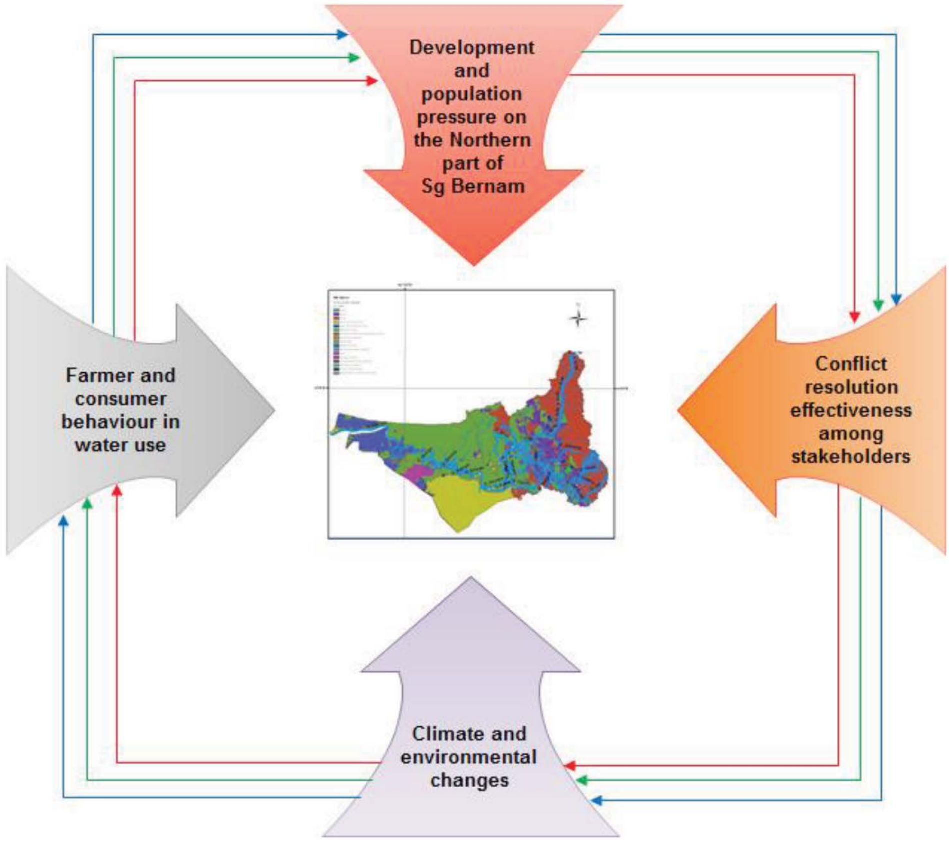



**Figure 6.6: The Institutional Gaps in Dealing with Nexus Challenges in the Sg Bernam Basin.**

Malaysia like most government subsidises irrigation water so heavily that farmers have little incentive to conserve water or invest in water saving methods. Although often perceived as politically unpopular, there is considerable scope for improving water management by correcting prices to equal the full marginal costs of supply.

Hard management or technological options are still the preferred methods as seen in the case of building a storage dam in response to the challenge water availability during drought. Pursuing a soft management option would imply minimisation of impacts of water system innovations on ecological values and key earth system processes, which underpin the adequate functioning of our societies, with social and economic values also being enhanced where possible. Such proposed directions aim to maintain the hydrological integrity and adaptive capacity of systems to support ecosystems. These may include encouraging responsible water usage for efficiency-sake, using standards of water that are fit-for-purpose to reduce treatment needs, and promoting local reuse of water to avoid extra energy use.

There appears to be no clear coordination among the different stakeholders in addressing nexus issues which also include environmental and climate challenges. For instance, there are views that a larger dam is needed in the upstream of Sg Bernam basin as a long-term measure to deal with climate change. Decisions on new water infrastructure along Sg Bernam seem are not made through stakeholder consultations with requisite attention on the nature of water challenges. Moving forward will also require capacity building in establishing input-output accounting to understand the nexus linkages and how to respond to their negative impacts.

# 7 SG KELANTAN BASIN

## 7.1 INTRODUCTION

Sg Kelantan is the major river in the state of Kelantan and is located in the Northeastern part of Peninsular Malaysia. The Sg Kelantan basin houses the second largest granary in Peninsular Malaysia which is managed by Kemubu Agricultural Development Authority (KADA). This basin is chosen as a case study mainly because KADA uses an energy-intensive water pumping system to irrigate the paddy fields. The changing river regime currently poses many operational challenges in the quest to ensure water and food security.

## 7.2 THE RIVER BASIN

### 7.2.1 River System and Land Use

Sg Kelantan has four main tributaries, namely Sg Galas, Sg Nenggiri, Sg Lebir and Sg Pergau. Figure 7.1 shows the river network of the Kelantan basin. The total length of the river from the head of its longest tributary is 388 km and drains an area about 13,000 km$^2$ occupying more than 85 percent of the Kelantan state. The main river, Sg Kelantan, with the length of about 105 km, is named for the stretch that emerges at the confluence of the Galas River and the Lebir River near Kuala Krai. It meanders over the coastal plain and flows through several populated cities such as Kuala Krai, Tanah Merah and the state capital of Kota Bharu until it finally reaches the South China Sea, approximately 12 km north of Kota Bharu. Sg Galas and Sg Lebir themselves have many tributaries, which provide the majority of the flow in the main Kelantan River. These tributaries rise into the forested mountains of Peninsular Malaysia.

Kelantan River Basin has a tropical climate receiving rainfall throughout the year. The maximum annual rainfall reaches 1750mm in the monsoon season (November– January). The average runoff for the Kelantan River Basin is approximately 500m$^3$/s.

The average annual precipitation in the Kelantan River Basin is about 2500 mm, while the average combined loss due to interception and evapotranspiration is around 1200 mm/year. The average annual runoff is therefore approximately 1300 mm. The average temperature is around 28.1 Celcius at Kota Bahru.

The basin is densely vegetated. Based on DOA's 2006 land use map (Figure 7.2), 5638.28 km$^2$ (44.25 percent) of the Sg Kelantan basin comprises state land forest and non-forest while the remaining 7104.13 square kilometres (55.75 percent) comprises permanent forest reserves (PFR) and National Parks which are excluded from any development. Out of the 5638.28 km$^2$ of land, 2595.05 km$^2$ (20.37 percent) of forest and 3,043.23 km$^2$ (23.88 percent) of non-forest land are committed to agriculture in the Sg Kelantan basin. The built-up area constitutes only 1.1 percent of the land-use. The future land use will not differ much concerning the types of land-use, but their percentages of areas will differ. The agricultural areas are likely to increase much more at the expense of the forested areas. The built-up areas are foreseen to increase steadily but not substantially.

## 7.3 WATER MANAGEMENT INFRASTRUCTURE

### 7.3.1 Rice Irrigation

KADA or Kemubu Agricultural Development Authority was established as a statutory body by Act 69 Laws of Malaysia, sited as *The Kemubu Agricultural Development Authority Act, 1972* which was enforced on 31 March 1972. KADA is responsible for the maintenance of four irrigation schemes, namely, the Kemubu Irrigation Schemes (20,430 ha), Lemal Irrigation Scheme (8630 ha), Pasir Mas Irrigation Scheme (1875 ha) and the Alor Pasir Irrigation Scheme (505 ha). The total area of land under the jurisdiction of KADA is about 60,500 ha of which 31,440 ha are provided with irrigation for double

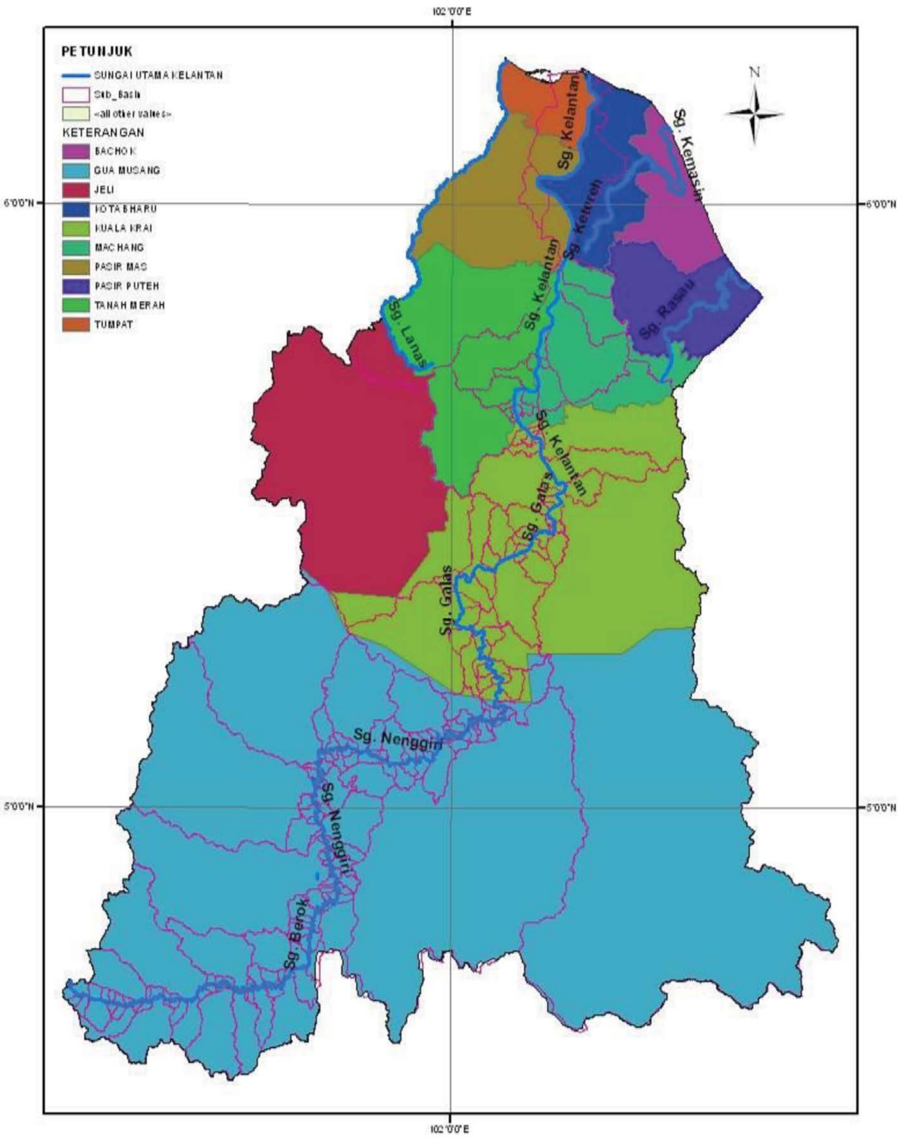



**Figure 7.1: Map of Sg Kelantan and its Tributaries.**

cropping of paddy. The Kemubu Scheme is situated on the East bank of the Kelantan River while the Lemal, Pasir Mas, and Alor Pasir Irrigation Schemes are on its West bank.

### 7.3.2 Pergau Hydropower

The Pergau or Sultan Ismail Petra Hydroelectric Power Station is located at Kuala Yong, one of the tributaries of Sg Kelantan in the upper reaches of the river. Pergau has an installed capacity of 600MW (4x150MW), the largest station in Peninsular Malaysia. This peaking plant can generate energy very fast at the rate of 15MW per second. It is a peak load underground station with an average generation of 520 GWh per year. The Pergau scheme is a major hydroelectric project including a 67m high whose operation is controlled remotely by the Bersia Group Control Centre, located 120 km from Pergau.

The Pergau scheme consists of an underground power station drawing water from a dam located on the Sg Pergau just downstream of its confluence with the Sg Yong. The flow capture of the scheme is enhanced by the pumped transfer of water from adjoining southern catchments through a 24 km long aqueduct. A re-regulating weir on the Sg Pergau in the vicinity of Kg Lawa controls outflow from the power station. The rock is primarily granite covered to a considerable depth by weathered material. Water from Sg Pergau is only 3 percent from Sg

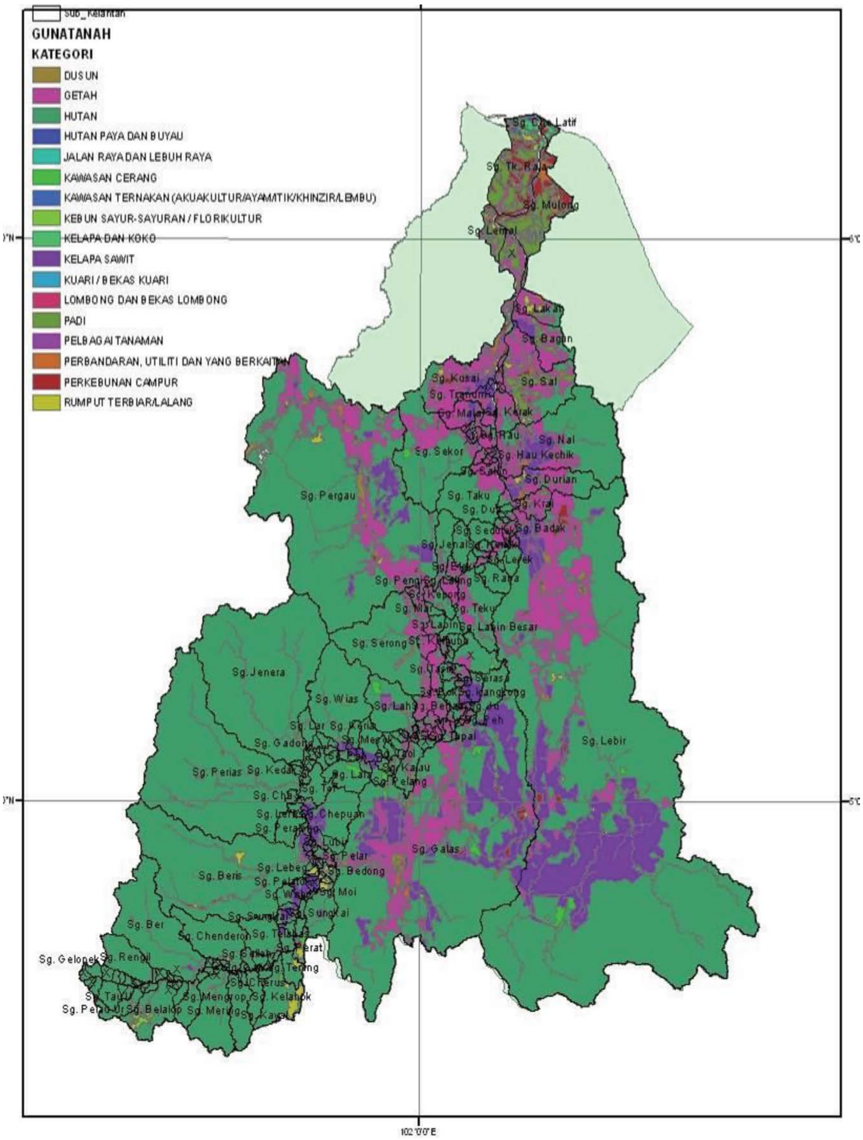



**Figure 7.2: Land Use in the Sg Kelantan Basin.**

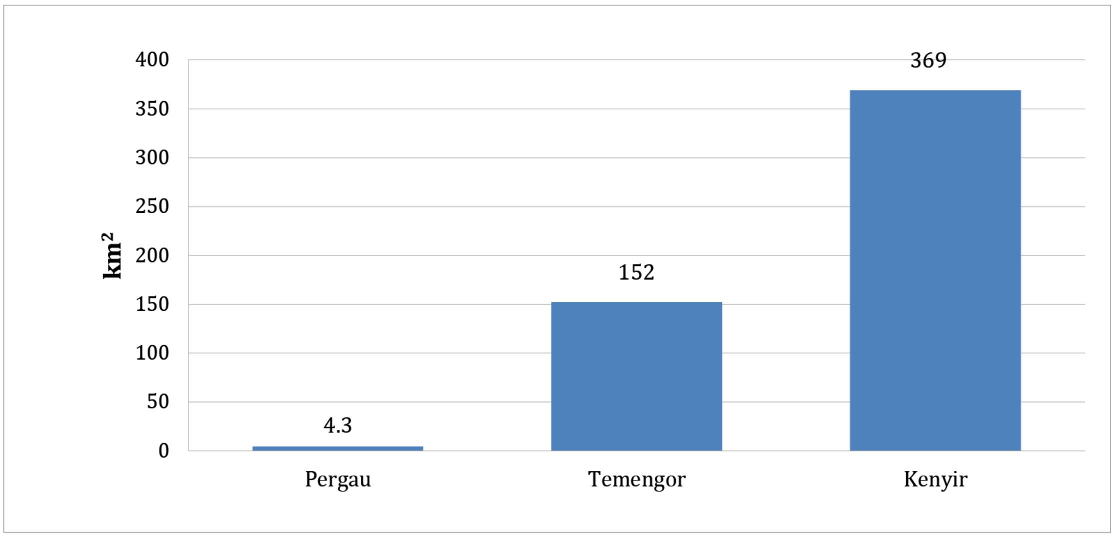



**Figure 7.3: Lake Area Comparison.**

Kelantan. The contribution of Pergau to floods control in Kelantan is therefore very minimum. Figure 7.3 compares the surface area of Pergau with Temengor and Kenyir dams. The Pergau infrastructure design is in keeping with the nexus approach whereby large energy capacity is generated using a small lake.

### 7.3.3 Water Treatment Plants

The main water resource for water supply in the state of Kelantan comes from direct river abstractions. Groundwater is also an important source, contributing to around 40 percent of raw supply for the state especially within the district of Kota Bharu. The water sector was privatised in October 1995 with Air Kelantan Sdn. Bhd. (AKSB) as the sole water provider in Kelantan.

Research by the Association of Water and Energy Research Malaysia (2011) highlighted some cases in Kelantan with low coverage performance, dirty and smelly water supply and frequent unscheduled interruption. Presently, water tariffs are low and unable to generate enough revenue to cover the full cost of capital investment, operation, and maintenance.

Based on current water tariff in Kelantan, the monthly water bill for a family of 4 members is around RM 8.00 if their water consumption is about 20 cubic meter ($m^3$). Even if we estimate the particular family consumes 30 cubic meter ($m^3$) of water monthly, the total cost is just about RM 15.50. This cost is insufficient for the Kelantanese to obtain clean, safe, and continuous supply of water.

Although Kelantan River is a clean river, certain physicochemical parameters (such as TSS, turbidity and nitrate concentration) had increased to extremely high levels that exceed the standards of the INWQS, as a result of sand mining activities and upstream logging activities (Lojing Highlands) (Tan and Rohasliney 2013). In the early 2000s, it was rare for TSS reading to reach 1000 NTU; currently, some of the plants have to treat water with a reading of 4000 NTU. Such high silt loads had caused the increase of cost of water treatment to about RM210,000 a month or RM2.5 million annually.

**Photo 7.1: Water intake point for the Kelar Water Treatment Plant.**

**Table 7.1: Water Treatment Plants Abstracting Water from Sg Kelantan.**

| Water Treatment Plant | District | Design Capacity MLD | Production MLD |
|---|---|---|---|
| Kelar | Pasir Mas | 64.00 | 60.57 |
| Merbau Chondong | Machang | 50.00 | 41.72 |
| Bukit Remah | Tanah Merah | 30.00 | 25.54 |
| Kuala Tiga | | 1.20 | 1.17 |
| Kg Tualang | Kuala Krai | 8.00 | 8.12 |
| Kuala Nal | | 2.00 | 1.44 |

## 7.4 WATER SECURITY CHALLENGES

The Sg Kelantan river basin is confronting increasing water demand, riverbank encroachment, environmentally damaging sand mining activities, and upstream land clearing projects. Together these problems present a water security threat to the functioning of Sg Kelantan river system and the health of its basin.

### 7.4.1 Irrigation Water Demand

Sg. Kelantan is the principal source of water for both the irrigation needs as well as the potable water demand for the state of Kelantan. The three most important water users are Kemubu and Kemasin-Semarak Granary area for irrigation and Kota Bharu Town for potable water. Water for Kemubu and Kemasin-Semarak Granary is provided by direct pumping from Sg. Kelantan via the Kemubu, Lemal and Pasir Mas pumping stations. For potable water supply to Kota Bharu Town, the water intake points are located near and downstream of the Kelar Treatment Plant.

### 7.4.2 River Encroachment

The Sg. Kelantan corridor is the most developed corridor within the study area regarding settlements, land-use, services and economic activities. Sg. Kelantan flowing through Kota Bharu town has very limited riparians on either side of the river. Many stretches of the river corridors of Sg. Kelantan has been encroached upon by human settlements. This transgresion reduces the ability of the buffer zone to filter sediments, retain nutrients and prevent pollutants from getting into the river.

The corridors of Sg. Nenggiri, Sg. Galas, Sg. Lebir and Sg. Pergau seems to be still surrounded by some natural vegetation. It is proposed that the riparian areas at those sections that have not been encroached upon by the development to be immediately zoned as river corridor reserves as reflected in the Conservation and Management Plan, based on the "Guidelines for the Development of Rivers and River Reserves" (JPS, 2001).

### 7.4.3 Sand Mining

In Sg. Kelantan basin, most of the sand mining activities concentrated along the main river of Sg. Kelantan from the river mouth to Kuala Krai. In a study by S&P Consultants, there are a total of about 70 sand mining abstraction points between Kota Bahru and Kusial. Among the observations they made are discussed below.

In the assessment of land development activities on the Sg. Kelantan basin, it was found that the sediment yield of all sub-catchment is on the rising trend, particularly so in the last decade or so. The order of sediment yield contribution in the Kelantan basin is as follows:

Galas > Kelantan > Lebir > Pergau > Nenggiri

In a nexus relationship, it was found that there exists a strong correlation between forest cover and sediment yield. Land development activities in the upstream clearly have a strong influence on sediment yield. The forest cover in the basin is gradually declining, suggesting the conversion of forest cover to other land use particularly oil palm and rubber plantation establishment. As of 2006, the remaining forest cover for the sub-catchment is as follows:

Nenggiri (91%) > Galas (77%) > Lebir (74%) > Pergau (73%) > Kelantan (72%)

The sediment yield in Lojing, or upland watersheds of the Nenggiri attachment, could range from about 800 to 22600 tonne/km$^2$/yr. The results of the S&P Consultants study also suggest that there is a correlation between loss of forest cover with sediment transport: the sediment yield concerning forest cover is as follows – Belatop (77 percent) > Jelai (87 percent) > Brook (93 percent). Stringent enforcement in needed to ensure the methods adopted in land preparations for crop establishment is sustainable considering the environmentally-sensitive landscape of Lojing. Extensive use of heavy machinery, particularly in cutting and leveling steep slopes had led to large quantities of soil being eroded and subsequently delivered to streams leading to high sediment loads.

### 7.4.4 Upstream Land Clearance

In recent years, many environmental issues have surfaced due to land development activities in the upland sub-catchments such as in Jajahan Gua Musang. With an area of 817,613 ha, it is the largest *jajahan* or district in the State of Kelantan, making up 64 percent of the total basin. Extensive land clearance activities in Jajahan Gua Musang for cropping, residential use, and infrastructural facilities have caused soil erosion and affected the water quality downstream of Sg. Kelantan. It has also affected the sub-catchments eco-tourism sites. An example of this is the Sg. Nenggiri and its sub-tributaries which are well-known areas for white-water rafting, sports fishing, and jungle trekking and caving. The water, however, is no longer clean and the eco-tourism is severely affected.

There is also a serious impact on the livelihood of the Orang Asli living in the area. The upper Sg. Kelantan basin, in particular, that of the Sg. Nenggiri, Sg Galas, and Sg. Lebir sub-catchments is home to one of the largest concentrations of Orang Asli settlements in the country. The total population of Orang Asli occupying the forests and valleys of these tributaries was estimated to be 11,712 persons, distributed over 127 villages. Large-scale forest clearance has inevitably cut into their foraging area. Silt and sediments carried downstream have affected the quality of their streams and food sources. Thus one of the objectives in the Conservation Plan is to address the sustainability of the traditional foraging areas and water quality for the Orang Asli in the upper Sg. Kelantan basin.

**Photo 7.2: Sand Mining Along Sg Kelantan Bank.**

## 7.5 WEF NEXUS

The Sg Kelantan basin is currently facing two nexus challenges. The first challenge has to do with the availability of water to irrigate paddy areas within the basin. The second is related to escalating cost of energy to pump water to the fields.

### 7.5.1 Water for Food Production

Sg Kelantan is the source of water for three irrigation schemes managed by KADA, namely Kemubu, Lemal, and Pasir Mas. A cluster of water pumping systems was developed in the 1960s with further improvements of their capacity and technology in the decades that follow (Table 7.2). The flow available in Sg Kelantan is much higher than the designed pumping amount. The design pumping capacity of the Kemubu Pumping Station is 58.6 $m^3/s$ compared to the minimum mean monthly flow in Sg. Kelantan which is 284 $m^3/s$. The flow rate (Q) needed for paddy irrigation is 95.4 $m^3/s$.

The changing regime of Sg Kelantan is affecting paddy production in the state. In recent years KADA has been facing the problem of being unable to pump the design amount many times in the past during dry seasons (Figure 7.4). The pumps could not function because the water levels in the major pumping stations are at below critical points for them to operate. For instance, on 28 April 2015, with the flow rate (Q) of 113 $m^3/s$, the water levels at Kemubu, Lemal and Kasa pump stations were 3.96 m, 0.22 m and 0.4 m respectively. All these readings were lower than the critical level of all three pump houses. The average water levels during drought seasons from 2010 to 2014 were 4.1 m for Kemubu, 0.5 m for Lemal, and 0.8 m for Kasa.

Also, the pump houses were also operating sub-optimally because of sedimentation of the river at the intake point. A study on land development activities in the Sg Kelantan basin by G&P Professionals Sdn Bhd suggested that the problem was caused by the following factors:

Table 7.2: KADA Irrigation Schemes.

| No | Irrigation Scheme | Area (hectare) | Pump Station | Capacity ($m^3/s$) | Requirement ($m^3/s$) | Pump Critical Level (m) |
|---|---|---|---|---|---|---|
| 1 | Kemubu | 20148 | Kemubu 1 & 2 | 58.6 | 45.8 | 4.9 |
| 2 | Lemal | 8708 | Lemal 1 & 2 | 24.5 | 21.6 | 1.6 (0.8 after improvement) |
| 3 | Pasir Mas | 2608 | Kasa | 4.6 | 6 | 1.07 |

- The falling water level in Sg. Kelantan which leads to a drop in water level in the pumping station during dry seasons.
- Siltation of the approach channel and the pump sump which would have compounded the problem of falling water level in Sg. Kelantan.
- The collapse and tilting of a certain stretch of steel pile weir has resulted in water level in Sg. Kelantan not being able to maintain at a high level.

This situation affects the water flow into the paddy production system. Thousands of farmers in KADA are facing the water supply crisis almost yearly due to the drought and irrigation failure. In fact, farmers are confronted with the water-rationing problem with their production and income from paddy cultivation significantly reduced. Over 3,000 farmers were affected around Kota Bharu Hulu, Kota Bharu Selatan, Pasir Puteh, Bachok and Pasir Mas with an estimated loss of RM100 million a year (Ismail 2013). Occasionally, water shortages have led to a conflict situation between the authorities and farmers. The Chairman of KADA in 2012 was quoted in the New Straits Times lamenting "Now the affected farmers simply accuse us of not pumping water into their paddy fields. They are unaware of the actual situation" (Anonymous 2012). As shown in Figure 7.5 paddy production for the whole of KADA scheme has been decreasing since 2009. The audit reported in the 2013 *Auditor General's Report* stated that "…the padi output in 2013 was only at 159,763 tonnes or 63.5 percent, compared to the set target of 251,750 tonnes".

Photo 7.3: Kemubu Pump House Complex.

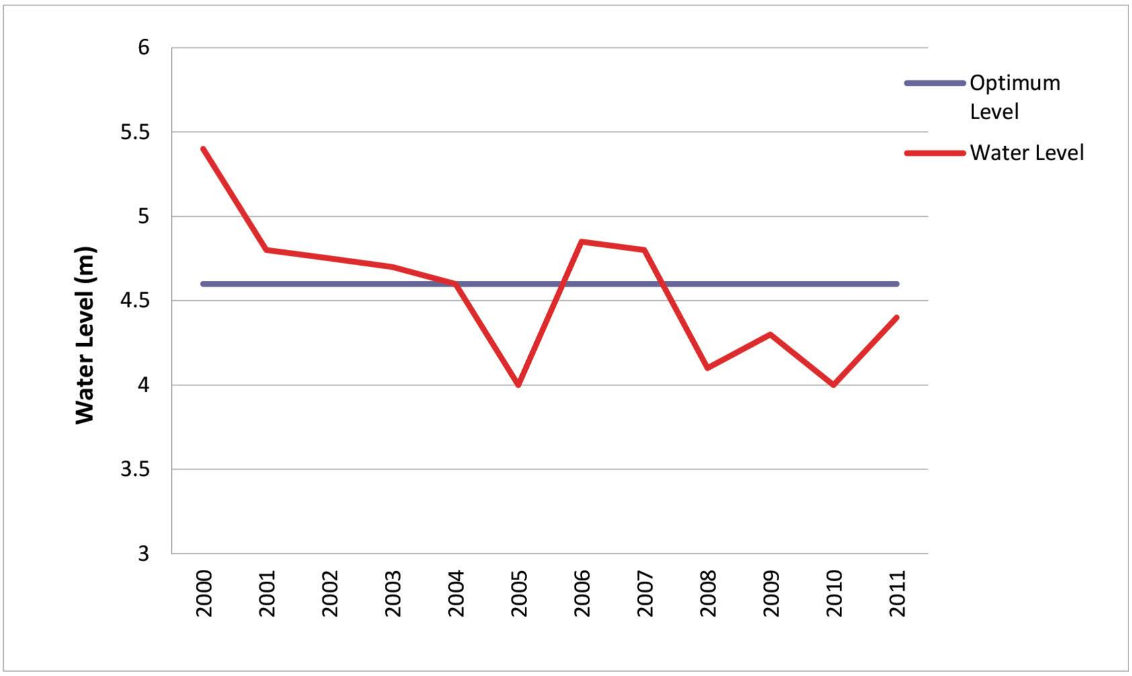



**Figure 7.4: Minimum Water level at Kemubu Pump Intake, 2000-2011.**

**Source: Kemubu Agricultural Development Authority, KADA.**

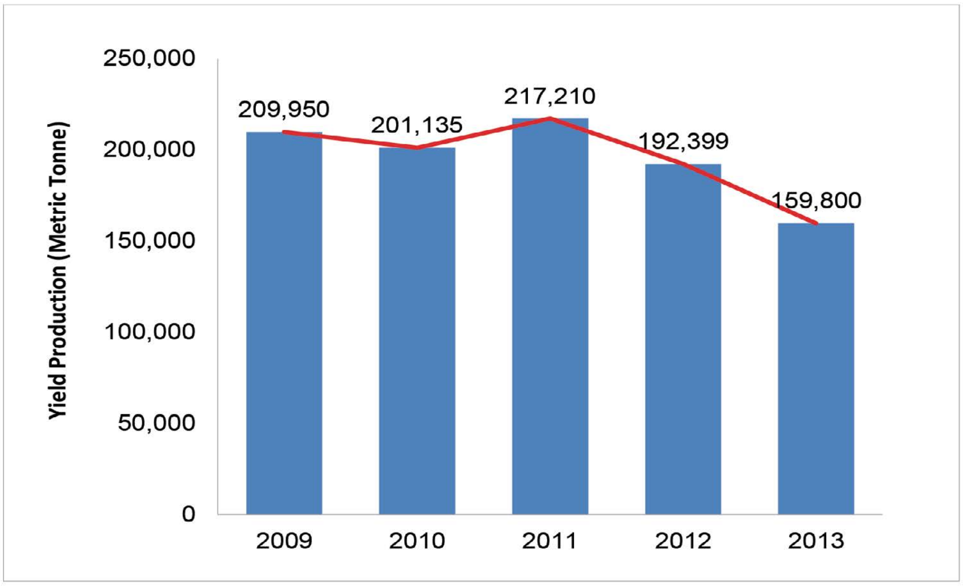



**Figure 7.5: KADA Paddy yield, 2009-2013.**

**Source: Kemubu Agricultural Development Authority, KADA.**


**Photo 7.4: Construction of low weir across Sg Kelantan.**

Since 2009, KADA has taken many short- and mid-term engineering measures to address the issue of inoperative pumping stations due to low river water level as well as massive sedimentation build-up within pumping intake areas:

- Construction of a low weir at Kemubu (1) Pumping Station to raise the water level of Sungai Kelantan to +4.90m with the cost of RM15 million.
- Modification of the pumping system at Kemubu (2) Pumping Station so that the pumps could operate at +3.43m water level instead of the previous +4.90m operating level with the cost of RM 500,000.00.
- Installation of a supporting pumping system for Kasa Pumping Station with the cost of RM 300,000.00.
- Design and fabrication of 40-tonne capacity excavator barge dredger and 5-tonne hydraulic cutter suction dredger for dredging works within pumping intake areas.

These measures have started to bear positive outcome in which KADA's paddy yield production for 2014 has increased 35 percent from 2013 with a total production of 216,000 metric tonne.

Besides these engineering measures stated above, there are two projects either being implemented, or in the conceptual stage which will serve as a long-term solution to the problem of irrigation water supply scarcity within 31,440 ha, KADA irrigated area. The first is the construction of a low weir at Kasa to raise the water level of Sungai Kelantan to +1.80m with the cost of RM38 million. This Tenth Malaysia Plan project which has taken off in 2013 is approaching its completion. The second one involves the upgrading of Kemubu Pumping System so that it could operate at a minimum water level of +2.0m against the existing operating level of +4.90m. The proposed project which is under Eleventh Malaysia Plan is scheduled to kick off in 2016 and completed in 2018. The main component of the project will involve with the installation of 10 units of screw pumps with total capacity of 34.2 $m^3/s$ at 12.5m total head. The cost of project is estimated at RM 50 million.

### 7.5.2 Energy for Food Production

The irrigation system to enable double cropping in areas under KADA's management is energy-intensive. When it started in the 1970s, this low-lift pumping scheme was powered by five diesel engines and included infrastructures such as a canal system to serve 19,000 ha; a drainage system, a flood protection levee; three diversion dams; booster pumps; and some buildings and other types of equipment. It was designed by French consultants (SOGREAH) with loan from the World Bank. In fact, electricity was proposed as the fuel of choice in the 1960s during conceptualisation stage, but its tariff was found to be unattractive.

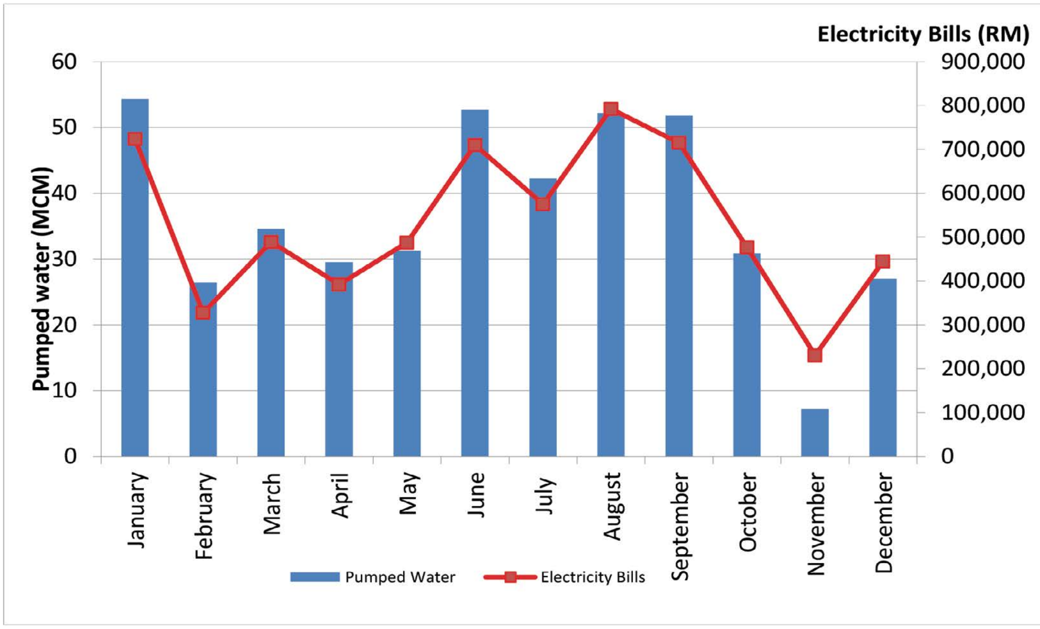



**Figure 7.6: Pumped Water and Electricity Bills at Kemubu Pump Station for the year 2014.**

The scheme adopted downstream control for the main canal and the pumping station and upstream control for the secondary system equipped with long-crested weirs and modular distributors. As in the MADA scheme in Kedah, the operational problem is the difficulty of controlling flows in the minor system and meeting the requirements of increasingly diversified cropping. Different control structures were later adopted for an extension of the scheme, consisting of adjustable flow-dividing structures.

By the 1970s, the price of diesel rose sharply leading to an increase in the operating cost. This had caused the system to operate sub-optimally and was unable to deliver its full design discharge and eventually suffered frequent breakdowns. The project engineers had to find ways to increase water use efficiency to reduce pumping costs. Energy cost continued to be prohibitive to the operation of irrigation in Kemubu. The World Bank (1971: p.iii) assessment of the Kemubu irrigation project provided the following conclusion:

> "None of the measures agreed to by Malaysia and the state of Kelantan, for the collection of water charges, an increased land tax and a special tax and a special tax on landlords, are yet to be carried out. In response to questions raised by the Bank, the Government has taken the position that no further action should be taken on cost recovery because farm incomes remain low, even with the project.

In 1975 KADA introduced rotational irrigation which had simultaneously reduced pumping costs and the peak load on the pumps and thus lessened the frequency of breakdowns. The cost of pumping in recent years is approximately RM5 million annually (see Figure 7.6 to Figure 7.11). In the year 2010 KADA has identified critical paddy cultivation areas and placed 162 portable pumps with various capacities within its irrigation areas to pump and irrigate water to the paddy fields. Similarly, in 2014, the Federal government had allocated an emergency RM400,000 allocation for farmers in Kelantan to buy portable pumps to channel water to their paddy fields due to the dry spell before the plants started wilting.

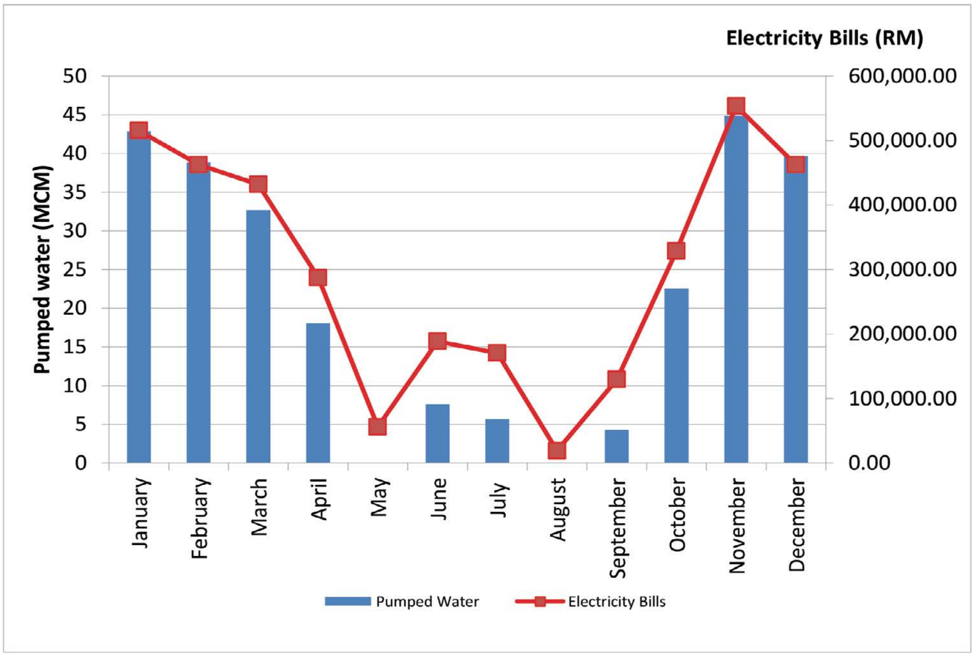



**Figure 7.7: Pumped Water and Electricity Bills at Kemubu Pump Station for the Year 2013.**

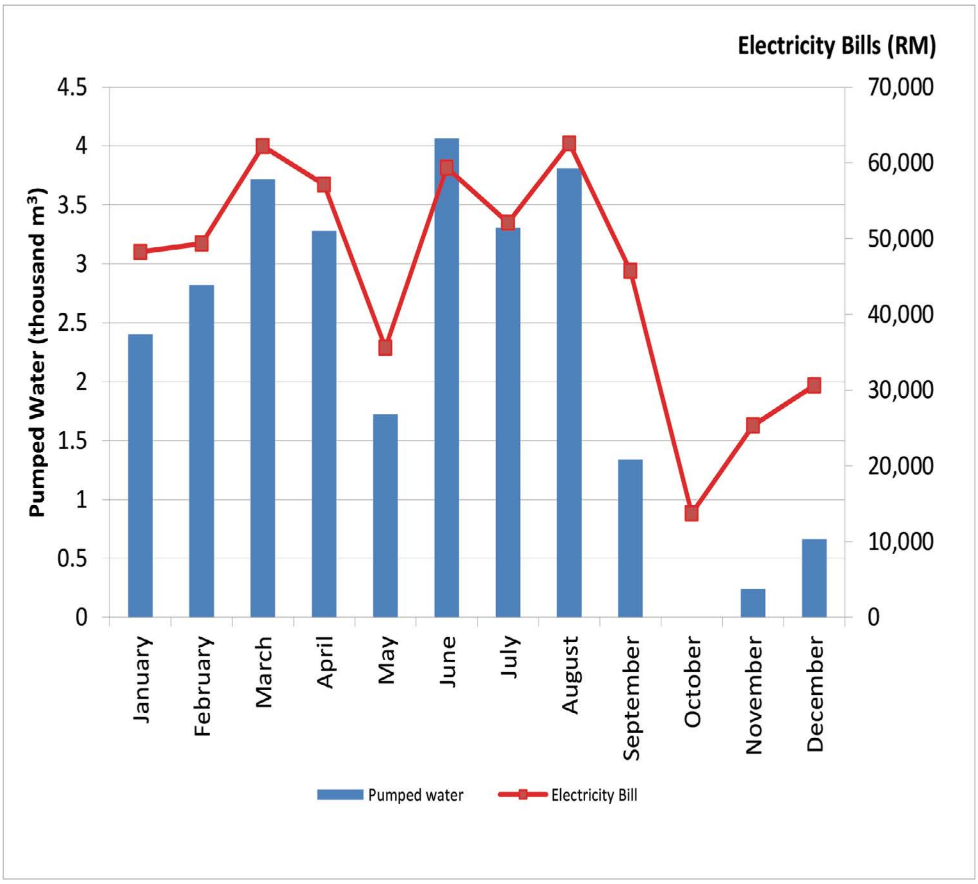



**Figure 7.8: Pumped Water and Electricity Bills at Kasa Pump Station for 2014.**

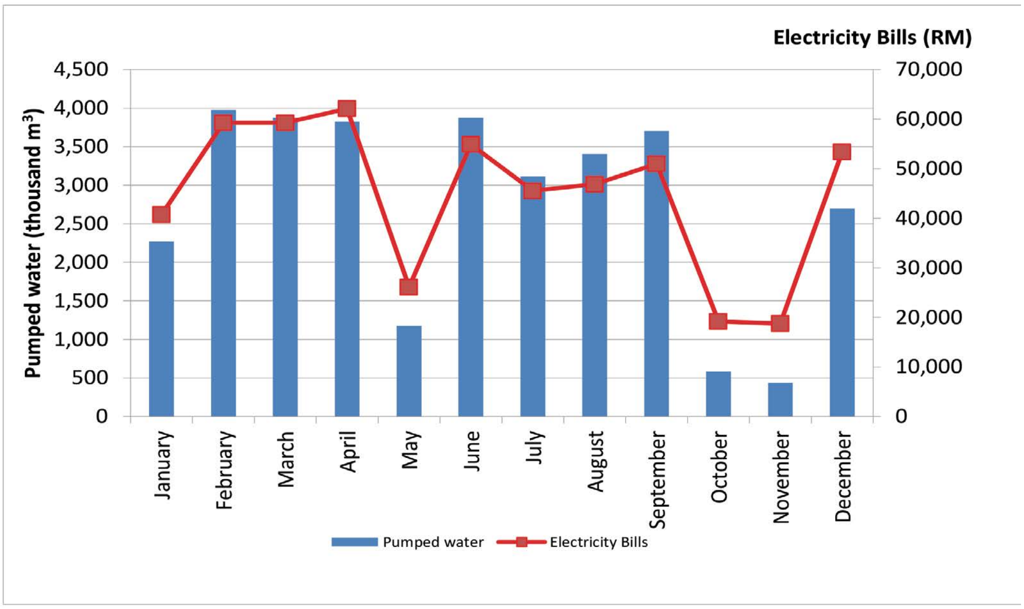



**Figure 7.9: Pumped Water and Electricity Bills at Kasa Pump Station for 2013**

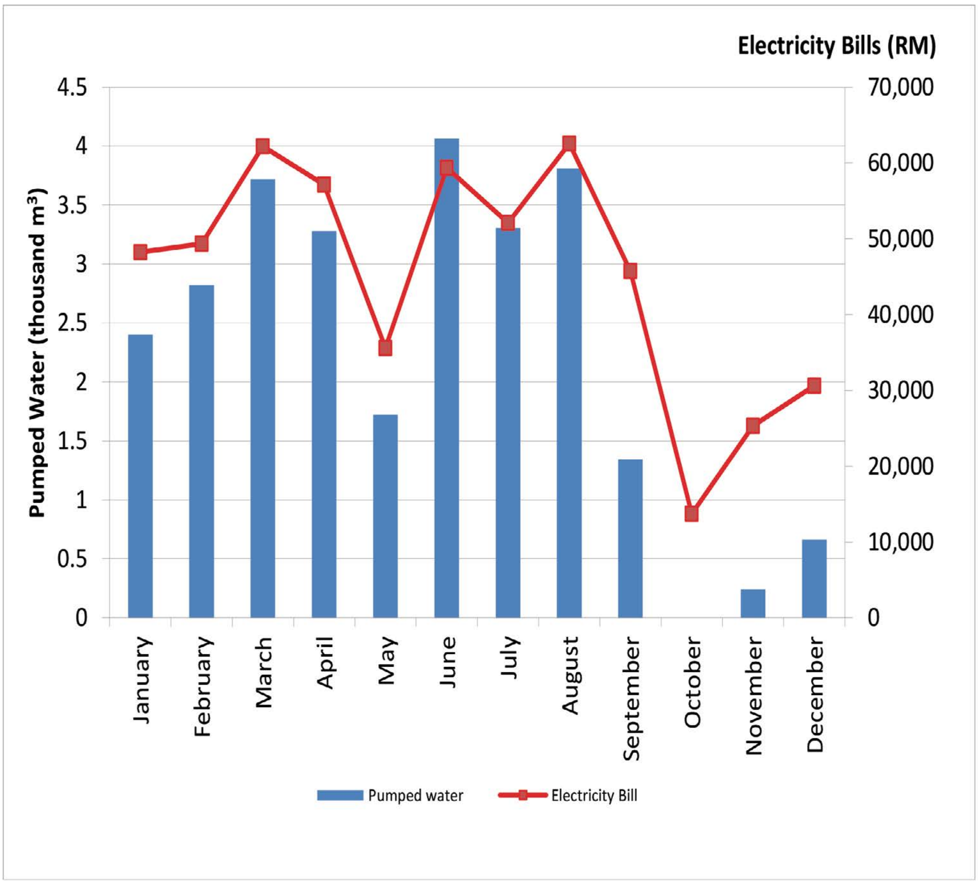



**Figure 7.10: Pumped Water and Electricity Bills at Lemal Pump Station for the year 2014.**

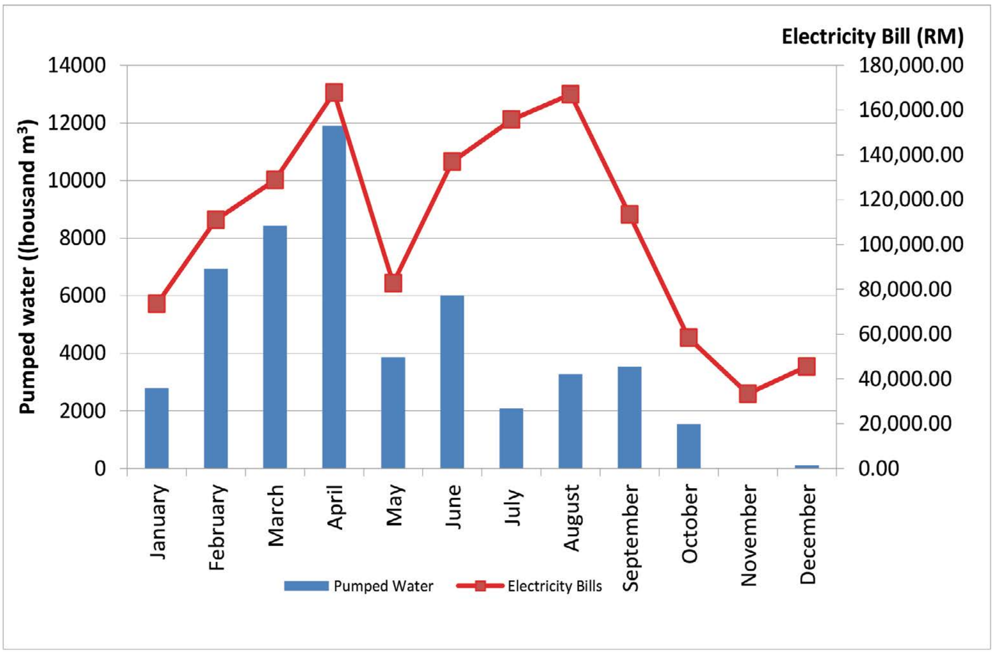



**Figure 7.11: Pumped Water and Electricity Bills at Lemal Pump Station for the year 2013.**

## 7.6 CONCLUSION

The Sg Kelantan river basin case study highlights the need for multiple but simultaneous interactions of multiple innovations across sectors. A challenge in the next few decades will be maintaining security of water supply in the Sg Kelantan river basin under the effects of climate change. Also, in the basin, a negotiation is ongoing about lowering the impact of floods by creating spare reservoir capacity in the upstream of Lebir and Nenggiri rivers. Unsustainable land use upstream and downstream of Sg Kelantan is compromising the long-term usability of water resources for agriculture. Also, the water supply sector in the basin has proven vulnerable to the water quality viz the worsening sedimentation of Sg Kelantan which led to forced shutdowns of water treatment plants.

It is widely known that investments to address one aspect of insecurity can exacerbate other aspects. To date, raw water supply shortfalls have been met by increased pumping, leading to higher energy costs in producing food. The keys to managing water supply under a diminishing resource are planning, integration and diversification of water sources, and community involvement.

# 8 SYNTHESIS AND RECOMMENDATIONS

## 8.1 STATUS OF WEF NEXUS

At the policy abstraction level, the Federal government recognises that the security of water, energy, and food resources are linked to one another. The Eleventh Malaysia Plan, 2016-2030 states the new direction whereby green growth is to underpin the country's development, "with an economy resilient to the adverse impact of climate change and with a secure and sufficient supply of natural resources such as water, food, and energy." The importance of working together in finding nexus solutions is also highlighted in the Plan: "Partnership and shared responsibility across all levels of society, including individuals, will be key to safeguarding the environment and biodiversity. Successful green growth will not only expand economic opportunities, but also enhance inclusivity and reduce disaster risks". Be that as it may, in comparative terms with the security narrative for energy and food resources, water security received the least regulatory and institutional backup in Malaysia's public policy.

From the three case studies, we conclude that the nexus framing, be it from the two- or three-way interaction between water, energy, and food resources, is relevant in Malaysia. The interactions exist in many forms, and they are and partially recognised thus far:

- While the nature or form of the interactions is traceable from a series of brief field study, the extent or degree of interactions introduces more complexity and hence understanding it will require a more focused and nuanced analysis.
- From the three case studies of mainly rural areas, we found that the nexus of water for food production and energy for food production are strongly present in the agricultural zones in Malaysia.
- Energy cost for water pumping even in gravity-fed areas is also increasing with the changing regime of river systems. This situation which exacerbated by climate change and worsening pollution.

Information gap, silo-based governance, and technology lock-in are the forces that hinder the translation of water, energy, food nexus into operationalisable objectives and programmes (see Figure 8.1).

- There is a dearth of information on nexus input-output. Establishing this 'internal linkages' (among resources) via input-output accounting is a major step in understanding the extent of nexus interaction in Malaysia.
- To complement the current governance approach, breaking down silos between different stakeholders and across the nexus is a key requirement for effective policy-making and resource management, but is also a stumbling block. Water, energy and food nexus is a whole-of-society problem whose governance is beyond the expertise of technocrats in the water sector. Although the 'big picture'or systems thinking is still a novelty at the state and district levels, resource managers have demonstrated interest to address the interconnectedness challenge. At the local and household levels, the nexus is a practical everyday reality.
- Large technological systems such as irrigation scheme and hydropower are hard to change because a country or an agency has sunk a lot of time, effort, and money into one of them. This choice makes the prospect of switching to a new technology incredibly challenging and expensive.

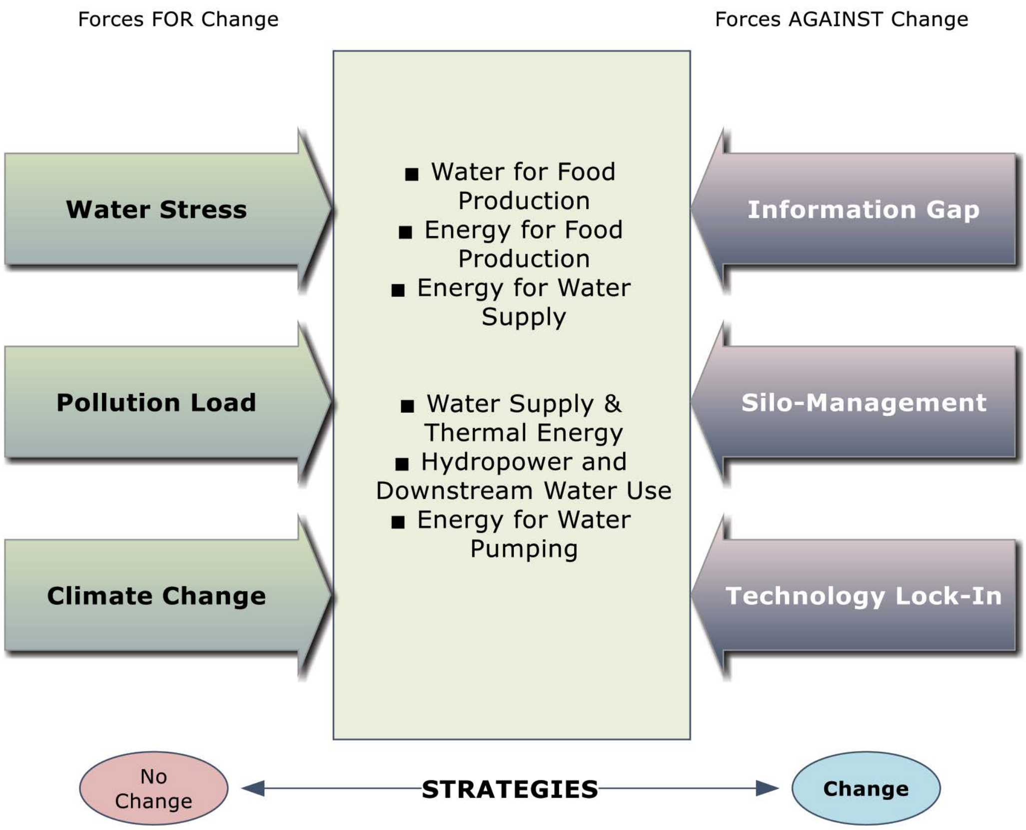



**Figure 8.1: Force Field Analysis for the Status of WEF Nexus in Malaysia.**

## 8.2 GENERAL RECOMMENDATIONS

### 1.Deepen understanding of 'internal' and 'external' water-energy-food nexus

1.1.The accounting of water-energy-food nexus needs to be more fully understood in terms of three metrics – physical (resource intensity and input-output linkages), monetary (price and cost dynamics) and distributive (implications of social allocations) at appropriate scales of governance.

1.2. Knowledge on the nexus should be co-produced with bodies and social forces such as relevant authorities, experts and stakeholder governing water, food and energy resources. Establishing national and basin levels data-hubs using Big Data Analytics is useful to enable social learning that can empower adaptive management.

1.3. While the security dimensions of water discussed in Chapter 3 revolved mainly around issues of availability, accessibility, affordability, efficiency, and sustainability, future studies must examine water security as seen from the perspective of water-related hazards from climate change or unregulated development. Also important is water needs for the ecosystem in which human survival is dependent upon. The impacts of rapid urbanisation, housing, and industries on water, energy and food challenges, including the pollution effect will also require a more expanded analysis in the future.

### 2. Encode the design principles in Water Resource Law or State Enactments that encourage and support initiative across water-energy-food nexus

2.1. Malaysia's policy style is predominantly top-down and legalistic. Thus, the implementation of the National Water Resources Policy requires a modernisation of the legal framework to support sustainable water management based on the nexus approach. Specifically, Malaysia should address the question how to encode the logic and design principles of water-energy-food nexus into statute laws at all levels of government. The purpose is to achieve the functional fit between 'hydrologically defined' water catchments and 'politically-defined' administrative boundaries, and more importantly, to encourage the optimisation of policies across water-energy-food nexus.

2.2. After all, 'security' is originally a military term which connotes 'securing an area'; by the same token, water authorities must be empowered legally and constitutionally with sufficient power to control the space, that is rivers and river reserves throughout the country.

2.3. The government must strengthen price signal to ensure productive and efficient use of resources. Removing price distortion and improving the target groups for energy, agriculture and water subsidies is one way of addressing this.

## 8.3 SPECIFIC RECOMMENDATIONS

### 3. Prioritise on water stress area, and conduct modeling of the interlinkages

3.1. To define basin-based criticality or thresholds as a basis to prioritise actions, the Government will have to initiate Input-Output nexus accounting in water deficit states and basins. The National Water Balance Study (NAWAB) for the selected river basins can utilise the Nexus framework as a starting point to calculate water footprint and the modeling of the interlinkages as the baseline for future in-depth analyses.

3.2. From this exploratory overviews study, the nexus hotspots include granary areas and water treatment plants within the Perak Tengah region, thermal station TNB Janamanjung, and water pumping stations such as Lemal and Kemubu in Kelantan.

### 4. Institutionalise a long-term view

4.1. To provide evidence to support longer-term thinking (30, 50, 100 years) in decision-making, establish Foresight Programme at national and especially at the state levels. The programme can publish State of the Water Resource periodically based on nexus assessment.

4.2. The national and state-level foresight may utilise global climate projections such as IPCC's Fifth Assessment Report. This information is to be used together with NAHRIM's national projections as well as projections of land use patterns and population by Town and Country Planning Department and Department of Statistics respectively.

### 5. Review and enforce existing environmental legislation to control river pollution

5.1. To reduce the pressure on the nexus, it is essential that a stronger enforcement capacity is put in place primarily to regulate activities defined under the *Environmental Quality Act 1974* and *Land Conservation Act 1960*. Regulation of sand mining or decision to clear forested area, for instance, should be guided by technical advice.

5.2. Where relevant, as in the case of Section 25 of *Environmental Quality Act 1974*, the effluent standards must be reviewed and revised to meet a higher level considering that most rivers are facing severe pollution stress. For instance, the effluent discharge standards for sewerage treatment plants as prescribed by the Department of Environment are deemed to be ineffective in meeting the country's objective to improve the quality of rivers. If not curtailed, the worsening pollution load challenge may exert greater pressure on the nexus of water, energy and food resources.

### 6. Create governance arrangements to break down silos

Modern public administration creates many organisations. Each orgnisation is expected to specialise to improve service delivery to citizens. Every organisation is also given its purpose, metrics, and support functions. One unintended consequence of organisation-centric governance arrangements is the fragmentation of responsibilities and authorities. Natural resources management suffers from the same functional silos with the conceptual separation and the consequent administration of these resources. The nexus approach aims to bring government and other stakeholders structurally into a horizontal discussion, as opposed to the current practice that is usually vertical, hierarchical and top-down. Applying a nexus approach does not necessarily require putting in place new 'nexus institutional set-up,' but rather, as a first step, to build on existing organisational structures and platforms and further broadening their scope with time.

6.1. At the National Level – At the highest political level, the Cabinet of Ministers need to be aware of the strategic nature of natural resources. Therefore, decisions regarding water, energy, and food security must be taken in cognisance of the interdependencies of each resource. Beyond the proceduralism of government that is governed by rigid rules of engagement, Malaysia also needs to open up a dialogue about natural resources futures through a process of constructive engagement involving the sectoral groups in the private sector and civil society. The former provides the persuasive power while the latter can contribute to nexus thinking by injecting the moral power, both complementing the coercive power of the government bureaucracy. One existing platform to host such horizontal dialogue is the newly established Sustainable Development Council with the Prime Minister as its chairman. Also, Malaysia needs a new development model based on circular economy principles, one whereby resource efficiency based on systems thinking is given a higher status than at present. The fourth thrust in the Eleventh Malaysia Plan – Pursuing Green Growth for Sustainability and Resilience – provides the basis for the long-term transition towards the new development model.

6.2. *At the State Level* – To facilitate comfortable engagement between stakeholders of water, energy, and food resources, the regular State Exco meetings or the State Planning Committee meeting can act as a neutral space to optimise decisions across the nexus. The platform can also function as a technology assessment forum. Also, State-owned think tanks such as Institut Darul Ridzuan (IDR) in Perak, The Penang Institute, and Institute Darul Ehsan (IDE) in Selangor can act as a conduit and platform to discuss the technical aspects of resource interlinkages.

6.3. *At the River-Basin Level* – In river basins with hydropower systems, there is a need to decentralise decision-making for hydropower operators to govern the discharge level of the upstream water resource. To optimise upstream and downstream water resources management, new Standard Operating Procedures to regulate water discharge are necessary. Existing river basin organisations such as *Lembaga Urus Air Selangor* (LUAS) and *Lembaga Sumber Air Negeri Kedah* are in a strong position to mainstream the nexus thinking by embracing multi-sectoral scope and broadening the base of its stakeholder groups from water to energy and food production sectors.

6.4. *At the District and Local Government Levels* – The district office as the front-line agency in policy and programme implementation as well as the grassroots connector, could serve as the platform to discuss nexus thinking and programme trade-offs between sectors. In practice, the discussion can be part of the agenda of the District Development Committee or other seminars and meetings under the chairmanship of the District Officer. Similarly, with urbanisation progressing rapidly, urban-based nexus solutions will require local governments to internalise nexus thinking in its policies and programmes.

# REFERENCES


Abdullah M.Y. 2007. Climate Change and Food Security, MARDI. Available at: http://www.undp.org.my/uploads/g_Food_security_MARDI.pdf

Academy Sciences Malaysia. 2015. *Strategies to Enhance Water Demand Management in Malaysia*. ASM; Kuala Lumpur.

Ahyaudin, B.A. 1996. Chenderoh Reservoir, Malaysia: the conservation and wise use of fish biodiversity in a small flow-through tropical reservoir. Lakes and Reservoirs, vol.2: 17-30

Aiken, R.S. and C.H.Leigh. 2011. Seeking Redress in the Courts: Indigenous Land Rights and Judicial Decisions in Malaysia. Modern Asian Studies. Vol.45(4): 825-875.

Aini, M.S., Fakhrul-Razi, A., Suan, K.S., 2001. Water crisis management: Satisfaction level, effect and coping of the consumers. *Water Resources Management*, 15: 31–39

Al-Amin, A.Q. and W.L. Filho. 2014. A return to prioritizing needs: adaptation or mitigation alternatives. Progress in Development Studies. Vo.14(4): 359-371

Allan, T., Keulertz, M., & Woertz, E. (2015). The water–food–energy nexus: an introduction to nexus concepts and some conceptual and operational problems. *International Journal of Water Resources Development*, (ahead-of-print), 1-11.

Allouche, J., Middleton, C., & Gyawali, D. (2015). Technical Veil, Hidden Politics: Interrogating the Power Linkages behind the Nexus. *Water Alternatives*, *8*(1), 610-626.

Andre, E. 2012. Beyond hydrology in the sustainability assessment of dams: A planners perspective – The Sarawak experience. Journal of Hydrology. Vol.142: 246-255

Arezki, R., Deininger, K., & Selod, H. (2015). What Drives the Global “Land Rush”?. *The World Bank Economic Review*, *29*(2), 207-233.

Aris, A. (2012, June 19). Subsidy must be targeted at the poor and needy. The Edge Malaysia. Retrieved from http://www.theedgemalaysia.com/commentary/215606-subsidy-must-be-targeted-at-the-poorand-needy.html

Arshad, F.M. and A.A.A. Hamed. 2010. Global Food Prices: Implications for Food Security in Malaysia. Journal of the Consumer Research and Resource Centre. Vol. March: 21-38

Bazilian, M., Rogner, H., Howells, M., Hermann, S., Arent, D., Gielen, D., ... & Yumkella, K. K. (2011). Considering the energy, water and food nexus: Towards an integrated modelling approach.*Energy Policy*, *39*(12), 7896-7906.

Bazillian, M., and others. 2012. Considering the energy, water and food nexus: towards an integrated modeling approach. Energy Policy, vol. 39: 7896-7906

Bhuiyan, S.I., Sattar, M.A., and M.A.K. Khan. 1995. Improving water use efficiency in rice irrigation through wet seeding. Irrigation Science. Vol.16: 1-8

Biggs, E. M., Bruce, E., Boruff, B., Duncan, J. M., Horsley, J., Pauli, N., ... & Haworth, B. (2015). Sustainable development and the water–energy–food nexus: A perspective on livelihoods. *Environmental Science & Policy*, *54*, 389-397.

Bizikova, L., Roy, D., Swanson, D., Venema, H. D., & McCandless, M. (2013). *The water-energy-food security nexus: Towards a practical planning and decision-support framework for landscape investment and risk management*. International Institute for Sustainable Development.

Bleischwitz, R., Hoff, H., Spataru, C.,van der Voet, E. and S.D VanDeveer. 2018. Handbook of the Resource Nexus. Routledge; New York.

Bringezu, S., & Bleischwitz, R. (Eds.). (2009). *Sustainable resource management: global trends, visions and policies*. Greenleaf Publishing.

Choy, Y.K. 2005. Energy demand, economic growth, and energy efficiency—the Bakun dam-induced sustainable energy policy revisited. Energy Policy. Vol. 33: 679-689.

Choy, F.K. and Z.A. Othman. 1996. Population Resettlement at Temengor Hydroelectric Project Malaysia. Paper Presented at the Third International Conference on Power Development Strategies for the 21st Century. 4-7 March, Kathmandu, Nepal.

Clay, J. 2004. World Agriculture and the Environment: A Commodity-by-Commodity Guide to Impacts and Practices. Island Press; Washington.

CSIRO and UNEP. (2010. 'CSIRO and UNEP Asia-Pacific Material Flows Online Database'.. Commonwealth Scientific and Industrial Research Organisation and and United Nations Environment Programme Available www.cse.csiro.au/forms/form-mf-start.aspx (accessed 21 October 2012).

Curmi, E., Fenner, R., Richards, K., Allwood, J. M., Bajželj, B., & Kopec, G. M. (2013). Visualising a Stochastic Model of Californian Water Resources Using Sankey Diagrams. *Water resources management*, *27*(8), 3035-3050.

Daher, B. T., & Mohtar, R. H. (2015). Water–energy–food (WEF) Nexus Tool 2.0: guiding integrative resource planning and decision-making.*Water International*, *40*(5-6), 748-771.

DeDatta, S. K. 1981. Principles and Practices of Rice Production. John Wiley, New York.

DOE. 2008. *Malaysian Environmental Quality Report*. Department of Environment. Kuala Lumpur.

Economic Planning Unit (EPU) and United Nations Country Team (UNCT). (2010). 'The Millennium Development Goals at 2010', Kuala Lumpur, Malaysia. Aini et al. 2001

Energy Commission (b). 2013. National Energy Balance. Kuala Lumpur.

Energy Commission. 2013. Performance and Statistical Information on Electricity Supply Industry in Malaysia, 2013. Kuala Lumpur.

Energy Commission. 2014. National Energy Balance. Kuala Lumpur.

ESCAP. (2013). United Nations Economic and Social Commission for Asia and the Pacific. The Status of the Water-Food-Energy Nexus in Asia and the Pacific. *Discussion Paper United Nations.*

Falkenmark, M., Lindh, G., 1993. Water and economic development. In: Gleick, P.H. (Ed.), Water in Crisis: A Guide to the World's Fresh Water Resources. Oxford University Press, New York, 80–91.

Gabungan 1999. The Resettlement of Indigenous People affected by the Bakun Hydro-Electric Project, Sarawak, Malaysia. A Report to the World Commission on Dams. The Coalition of Concerned NGOs on Bakun (Gabungan).

Gold, H. D., & Bass, J. (2010). Energy-Water Nexus: Socioeconomic Considerations and Suggested Legal Reforms in the Southwest, The.*Nat. Resources J.*, *50*, 563.

Granit, J., Jägerskog, A., Lindström, A., Björklund, G., Bullock, A., Löfgren, R., ... & Pettigrew, S. (2012). Regional options for addressing the water, energy and food nexus in Central Asia and the Aral Sea Basin. *International Journal of Water Resources Development*, *28*(3), 419-432.

Gu, A., Teng, F., & Wang, Y. (2014). China energy-water nexus: Assessing the water-saving synergy effects of energy-saving policies during the eleventh Five-year Plan. *Energy Conversion and Management*, *85*, 630-637.

Gulati, M., Jacobs, I., Jooste, A., Naidoo, D., & Fakir, S. (2013). The Water–energy–food Security Nexus: Challenges and opportunities for food security in South Africa. *Aquatic Procedia*, *1*, 150-164.

G&P Professionals. 2010. Study of the Impacts of Land Development Activities on Water Resources of Sg Kelantan and the Development of a Conservation Plan. Executive Summary for Final Report. Unpublished Study Prepared for the Department of Irrigation and Drainage, Government of Malaysia. Kuala Lumpur.

Halbe, J., Pahl-Wostl, C., A. Lange, M., & Velonis, C. (2015). Governance of transitions towards sustainable development–the water–energy–food nexus in Cyprus. *Water International*,*40*(5-6), 877-894.

Hartmann, J. 2013. Economic Perspectives on Sarawak Hydropower Development. Unpublished Study for WWF Sarawak; Kuching.

Hezri, A.A. 2016. *The Sustainability Shift: Refashioning Malaysia's Future*. Areca Books; Penang.

Hezri, A.A. & M. Kwa. 2018. Resources Nexus: The Importance for Asia and the Role of Institutions. In: Marsden, T. (ed.), The Sage Handbook of Nature. Sage Publishers; London, pp. 1218-1244.

Hoff, H. 2011. Understanding the Nexus: Background paper for Bonn 2011 Conference: The Water, Energy and Food Security Nexus. Stockholm: Stockholm Environment Institute Report.

Hussey, K., & Pittock, J. (2012). The energy–water nexus: managing the links between energy and water for a sustainable future. *Ecology and Society*, *17*(1), 31.

IPCC 2013.IPCC Climate change 2013. The Physical Science Basis Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

ISIS Malaysia. 2014. Reform in Peninsular Malaysia's Electricity Sector. ISIS Malaysia Kuala Lumpur.

Jaafar, A. B. (1998). 'Two Decades of Environmental Quality Management in Malaysia,

Jansen, L., Sidek, L.M., Desa, M.N.M., and P.Y. Julien. 2013. Hydropower Reservoir for Flood Control: A Case Study on Ringlet Reservoir, Cameron Highlands, Malaysia. Journal of Flood Engineering. Vol.4(1): 87-102.

JICA. 1987. Feasibility Study on the Tanjong Karang Irrigation Development and Management Project. Japan International Cooperation Agency and the Government of Malauyia.

Jobbins, G., Kalpakian, J., Chriyaa, A., Legrouri, A., & El Mzouri, E. H. (2015). To what end? Drip irrigation and the water–energy–food nexus in Morocco. *International Journal of Water Resources Development*, (ahead-of-print), 1-14.

JPBD. 2010. *National Physical Plan 2*. Town and Country Planning Department; Kuala Lumpur.

JPS Perak Tengah. 2014. *Kertas Kerja Justifikasi Untuk Permohonan Peruntukan Bagi Projek Menaiktaraf Kawasan Pengairan Luar Jelapang di Daerah Perak Tengah, Negeri Perak Darul Ridzuan*. Jabatan Pengairan dan Saliran Perak.

JPS Malaysia. 2010. Sungai Perak State of the River 2010. Jabatan Pengairan dan Saliran & G&P Professionals.

Koutsoyiannis, D., 2006. Nonstationarity versus scaling in hydrology: Journal of Hydrology, 324, 239–254.

Keskinen, M., Someth, P., Salmivaara, A., & Kummu, M. (2015). Water-energy-food nexus in a transboundary river basin: The case of Tonle Sap Lake, Mekong River Basin. *Water*, *7*(10), 5416-5436.

KRI. 2014. The State of Household. Khazanah Research Institute; Kuala Lumpur

Kun, C.F. and D.H. Saman. 2004. Cameron-Highlands and Batang padang Hydroelectric Scheme: Dam Surveillance and Performance Review. In: Wieland, M., Ren, Q, and Tan, J.S.Y (eds.), New Developments in Dam Engineering. London; Taylor and Francis Group, pp. 263-271.

Laldjebaev, M. (2010). The water–energy puzzle in Central Asia: the Tajikistan perspective. *Water Resources Development*, *26*(1), 23-36.

Lee, C. 2005. Water Tariff and Development: The Case of Malaysia. Centre on Regulation and Competition Working Paper. Manchester University; United Kingdom.

Lee, K.F. 2009. A Background Study: Economic Benefits of the Muda Water Catchment. WWF-Malaysia.

Lele, U., Klousia-Marquis, M., & Goswami, S. (2013). Good governance for food, water and energy security. *Aquatic Procedia*, *1*, 44-63.

M. Howells, S. Hermann, M. Welsch, M. Bazilian, R. Segerström, R. Alfstad, D. Gielen, H. Rogner, G. Fischer, H. van Velthuizen, D. Wiberg, C. Young, A. Roehrl, A. Mueller, P. Steduto, I. Ramma. (2013). Integrated analysis of climate change, land-use, energy and water strategies. *Nat. Clim. Change, 3 (2013), pp. 621–626*

Malaysia. 1974. *Environmental Quality Act 1974* (Act 127). Government Printing; Kuala Lumpur.

Malaysia. 2015. The Eleventh Malaysia Plan. Government of Malaysia; Kuala Lumpur.

Malaysian Water Association. 2015. Malaysia Water Industry Guide 2015. MWA; Kuala Lumpur.

Malik, R. P. S. (2002). Water-energy nexus in resource-poor economies: the Indian experience. *International Journal of Water Resources Development*, *18*(1), 47-58.

Mayor, B., López-Gunn, E., Villarroya, F. I., & Montero, E. (2015). Application of a water–energy–food nexus framework for the Duero river basin in Spain. *Water International*, *40*(5-6), 791-808.

Meza, F. J., Vicuna, S., Gironás, J., Poblete, D., Suárez, F., & Oertel, M. (2015). Water–food–energy nexus in Chile: the challenges due to global change in different regional contexts. *Water International*, *40*(5-6), 839-855.

Milly, P.C.D., J. Betancourt, M. Falkenmark, R.M. Hirsch, Z.W. Kundzewicz, D.P. Lettenmaier, and R.J. Stouffer, 2008. Stationarity Is Dead: Whither Water Management?: Science, 319, 573-574

Ministry of Natural Resources and Environment. 2010. National Water Resources Study. Kuala Lumpur.

Ministry of Natural Resources and the Environment. 2010. *Sungai Perak Basin Management Plan*. Department of Irrigation and Drainage; Kuala Lumpur.

MoAAF. 2015 – *Agro-food Statistics 2014. Ministry of Agriculture and Agro-Food. ; Kuala Lumpur.*

MoAAI. 2008. Malaysia National Report: Follow-Up on the Implementation of the World Food Summit Plan of Action. Ministry of Agriculture and Agro-Based Industry; Putrajaya.

Mohd Akbar Hj and R. Rusnah. 2004. Water resources management for domestic and industrial needs. In: Abdul Rahim N (ed) *Water: forestry and land use perspectives*, Technical Documents in Hydrology No. 70, International Hydrological Programme. UNESCO, Paris, pp 1–15.

Mohd Suhaily and Reid 2010. The Impact of Land Use Change on Water Yield: The Case Study of Three Selected Urbanised and Newly Urbanised Catchments in Peninsular Malaysia. In: P. Zdruli et al. (eds.), Land Degradation and Desertification: Assessment, Mitigation and Remediation. Springer; New York, pp.347-354.

Mohd Suhaily, Y.C.N., Hashim, M., Nayan, N., Saleh, Y. and Z.M. Said. 2008. Analisis Guna Tanah dan Implikasinya terhadap Persekitaran Fizikal Lembangan Sungai Bernam 1984-2004. Jurnal Perspektif. Vol.6: 19-35

Othman, J., Goh, H.P. and Y. Jafari. 2014. Benefits Valuation of Potable Water Quality Improvement in Malaysia: The Case of Kajang Municipality. *International Journal of Water Resources Development*. Vol.30(4): 621-634

Ozment, S., DiFrancesco, K., Gartner, T. (2015) *The role of natural infrastructure in the water, energy and food nexus*, Nexus Dialogue Synthesis Papers. Gland, Switzerland: IUCN

PBAPP. 2014. Powerpoint Presentation at the Seminar on Climate Change: Burning Question for the Media. Penang Water Authority; Penang.

PETRONAS. 2013. Corporate Sustainability Report 2013. Kuala Lumpur.

PETRONAS. 2014. Corporate Sustainability Report 2014. Kuala Lumpur.

Puncak Niaga. 2014. Annual Report 2014. Puncak Niaga Sdn Bhd; Shah Alam.

Ranhill Consulting. 2011. *Review of the National Water Resources (2000 - 2050) and Formulation of National Water Resources Policy*. Unpublished Report; Kuala Lumpur.

Rasul, G. (2014). Food, water, and energy security in South Asia: A nexus perspective from the Hindu Kush Himalayan region. *Environmental Science & Policy*, *39*, 35-48.

Sachs, J. D. and Warner, A. M. (1995). 'Natural Resource Abundance and Economic Growth', National Bureau of Economic Research Working paper No. 5398, Cambridge, MA.

Scott, C. A., Pierce, S. A., Pasqualetti, M. J., Jones, A. L., Montz, B. E., & Hoover, J. H. (2011). Policy and institutional dimensions of the water–energy nexus. *Energy Policy*, *39*(10), 6622-6630.

Sharifuddin, S. 2014. Methodology for quantitatively assessing the energy security of Malaysia and other southeast Asian countries. Energy Policy. Vol.65: 574-582

Sibon, P. 2015. Bakun HEP Dam to produce 1,700MW of HEP by 2016. The Borneo Post. 12 November.

Siddiqi, A., & Anadon, L. D. (2011). The water–energy nexus in Middle East and North Africa.*Energy Policy*, *39*(8), 4529-4540.

Sovacool, B. and Bulan. 2011. Behind an ambitious megaproject in Asia: The history and implications of the Bakun hydroelectric dam in Borneo. Energy Policy. Vol.39: 4842-4859

Tey Y.S. and A. Radam. 2011. Demand patterns of rice imports in Malaysia: Implications for food security. Food Security. Vol.3: 253-261

Tey, Y.S. 2010. Malaysia's Strategic Food Security Approach. International Food Research Journal. Vol.17: 501-507

Tick, H.O., Shing, C.C., and W.W. Goh. 2011. Bakun – Where Should All the Power Go? *Renewable and Sustainable Energy Reviews*. Vol.15: 1035-1041.

TNB. 1993. Hydro Power in Malaysia. Tenaga Nasional Berhad; Kuala Lumpur.

TNB. 2010. Tenaga Nasional Berhad Annual Report 2010. Kuala Lumpur.

Vaghefi , N., Shamsudin, M.N., Makmom, A. and M. Bhageri. 2011. The economic impacts of climate change on the rice production in Malaysia. International Journal of Agricultural Research. Vol.6(1): 67-74.

Villamayor-Tomas, S., Grundmann, P., Epstein, G., Evans, T., & Kimmich, C. (2015). The Water-Energy-Food Security Nexus through the Lenses of the Value Chain and the Institutional Analysis and Development Frameworks. *Water Alternatives*, *8*(1), 735-755.

Vincent, J. R. and Ali, R. M. (1997). Environment and Development in a Resource-Rich Economy: Malaysia under the New Economic Policy, Cambridge, USA: Harvard University Press.

Walker, R. V., Beck, M. B., Hall, J. W., Dawson, R. J., & Heidrich, O. (2014). The energy-water-food nexus: Strategic analysis of technologies for transforming the urban metabolism. *Journal of environmental management*, *141*, 104-115.

Wong. L.C.Y. 2012. Food Security and Growth: Malaysia's Strategic Approach and Future Adjustments. *CRRC Consumer Review*. March Volume: 34-44.

World Bank. (2010). 'World Bank Data Bank'. Available http://data.worldbank.org/indicator/ (accessed 20 August 2012).

Yen, T.P. and H. Rohasliney. 2014. Status of Water Quality Subject to Sand Mining in the Kelantan River, Kelantan. *Tropical Life Sciences Report*. Vol.24(1): 19-34

Zainab, H. 2007. Climate Change Adaptation and the Water Sector: The Malaysian Experience. Powerpoint Presentation accessible at http://www.ukm.my/myc/updates%20140809/paper/3-3_NAHRIM.pdf

Zakaria, S. 2013. Water Resource Management Issues in Malaysia. In: P. O. Lee (ed.), *Water Issues in Southeast Asia: Present Trends and Future Directions*, Singapore: ISEAS, 119–35.

ISBN 978-983-9304-41-1

**National Water Balance Study (NAWABS)**
**Water Resources and Hydrology Division**
**Department of Irrigation and Drainage**
**Ministry of Water, Land and Natural Resources**
**Jalan Sultan Salahuddin**
**50656 Kuala Lumpur, Malaysia.**