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Serwan M. J. Baban

Managing Geo-Based Challenges

World-Wide Case Studies and Sustainable Local Solutions

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Preface

In the majority of developing countries, the current approach to management and decision making regarding geo-based challenges tends to be defective for a number of reasons. These include, first, the nature of the decision-making process which is often subjective and reactive. Then, once the proposed objectives fail to materialise, the efforts tend to focus on managing and containing operations post event. Hence, mitigation actions are often designed to ‘repair’ and ‘minimize the negative impacts’ after the event. Secondly, information poverty is a restraining factor and, finally, the inability for developing sustainable management options based either on producing locally applied research or utilising relevant international research.

Experience shows that subjective and reactive decisions, actions and practices typically lead to eroding public rights and to continuous degradation of the environment and natural resources, i.e. water, soil, air, natural habitats and biological diversity. The consequences of these degradations can slow down the pace of development and threaten the process of nation building.

Evidently, there is a great need to enhance the process for, and to develop the capabilities for objective decision making and to move from being reactive to proactive. This objective requires managing the information poverty obstacle and energising research thinking and problem solving through enabling international level scientific research, capable of producing research-based solutions and sustainable management options.

The literature is poor in this domain and none seem to show the way forward or to present real and practical case studies utilising new technologies, scientific thinking and factoring in local conditions for informing the decision-making process and to develop effective policies.

This book presents the sustained and continuous research activity of the author over some three decades which was developed based on a multidisciplinary geo-based background and an enduring interest in understanding and managing issues and challenges facing developing countries, especially from the perspective of their processes and impact, and the ways in which applied science can provide a sound basis for informed decisions making. In fact it is based on a Doctor of Science (D.Sc.) thesis in Geo-Based Environmental Sciences submitted to the School of Environmental Sciences, University of East Anglia, Norwich, UK. The D.Sc. degree was obtained successfully by the author during February 2011.

The book is designed to provide information, advice, guidance and a sound conceptual framework for readers interested in using Geoinformatics to address geo-based challenges and to enhance decision making especially in developing countries. In addition, the necessary technical tools are explored and used to energise research thinking in a way that can develop locally driven practical and sustainable solutions. Consequently, moving the management of geo-based challenges away from reactive and towards proactive approaches. To facilitate the process, worldwide case studies based on the author's first-hand experiences in Arid/Semi Arid (Iraq, Tunisia, Morocco and Jordan), Temporal (UK) and Tropical environments (Malaysia, the Caribbean region, Indonesia and Australia) are presented. The ultimate goal is to influence future development choices and contribute to realizing sustainable futures and nation building.

In terms of readership, this publication is meant to assist researchers, students and interested readers with research and consultancy dealing with applied local and relevant issues and assist with capacity building necessary for the development processes. In a formal sense, it is most suited for researchers, postgraduate and advanced undergraduate students interested in:

1. Research Methodologies focusing on both the 'deductive' and the 'inductive' approaches for conceptualising and finding science-based sustainable solutions for geo-based challenges.
2. Using Geoinformatics to manage multidisciplinary Geo-based challenges.
3. Applications focused on Geo-Sciences, Disaster Management, Water Resources, Land use/cover mapping, Agriculture, Biodiversity, Climate change, Suitability and Sustainable Development Studies.
4. Higher Education and University Governance issues and challenges with a focus on developing countries.

Serwan M. J. Baban
March 2014

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1.1 Introduction

Throughout my career, I have been interested in research; I enjoy finding the interesting and complex connections between sometimes equally complex ideas. I am also interested in the practical applications of geosciences scientific concepts under different physical and environmental conditions.

As a busy professional, I tend to spend a significant time on the detailed work of the day, whether it be planning for meetings, following up on previous actions, deliverables and timelines, meeting stakeholders, conducting field visits, writing or reviewing research papers or any management and governance issues of the day.

Having been asked by research students and colleagues to repeatedly explain the drivers for my research and how, through a reflective process, I learned from my experiences and if any useful lessons can be derived and of use for others. This in parallel with the invitation to apply for a D.Sc. from the prestigious School of Environmental Sciences, University of East Anglia in the UK, challenged me to look back and see my work in perspective. More specifically, the challenge presented to me was to reflect on what I have accomplished, to consider what has motivated me, and to discuss what I have learned throughout my career as a scientist and a manager.

Therefore, I felt the need to reflect on my own career and attempt to rationalise and explain my practice-based experience to produce learning, hence, being a Geoscientist, I realised the importance of examining the big picture and standing back to observe and examine large geological; structures and phenomena as well as being as objective as possible.

Consequently, to me and as Dillard (2006) indicates; the primary task is to clarify the relevant terms/concepts that appear to be critical to a discussion of paradigm propagation and its meanings for research and teaching. This to me embrace the unpacking the idea of paradigms and finding some clarity and location of my own scholarship trajectory in relation to the field, as well as my identity location as a specialist in Geosciences, Environmental Science, in Geoinformatics (Environmental Remote

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Fig. 1.1 A reflection model based on Gibbs (1988)

Sensing and GIS) as well as Management and Governance with a multi-disciplinary Geo-based background and working experience in Arid/Semi Arid (Iraq, Tunisia, Morocco, and Jordan), Temporal (UK) and Tropical environments (Malaysia, the Caribbean region, Indonesia and Australia).

In order fulfill the necessary requirements for this undertaking, I needed to follow the reflective writing's path, as it includes description (what, when, who) and analysis (how, why, what if). Hence, it will provide a tool to draw theory or concepts from observations based on generalization and to use the acquired knowledge to effectively explore new situations terms of thoughts and actions. In addition it will provide a tool to reflect on mistakes, learn to avoid them, and successes, identifying correct principles and use them again (Gibbs 1988).

I broadly used Gibbs (1988) model of reflection (Fig. 1.1), which outlines the stages for a 'Structured Debriefing' and encourage deeper reflection. Furthermore, at times, I relied on Bloom (1964) hierarchy which identified different levels of thinking processes (Fig. 1.2). I felt it will help me with evaluating the process and the outcomes, clarifying the connections between my theory and practice as well as between the approach /methodology and how to conduct the research and how to manage all related issues. This approach can be used as a framework for more thorough reflection. It moves from knowing, evidenced through recalling information, through to evaluating, evidenced through making systematic judgments of value.

Over all, I found writing this book more challenging than other forms of academic writing as it involved reflecting and writing about anxieties, difficult and uncertain times as well as successes over some three decades. This writing, I found, also required linking my experiences with relevant schools of thoughts and theories, how can the theories help to interpret my experience? how my experience

Increasing Difficulty	Process	Explanation
↓	Knowledge	Recognition and recall of information - describing events
	Comprehension	Interprets, translates or summarises given information - demonstrating understanding of events
	Application	Uses information in a situation different from original learning context -
	Analysis	Separates wholes into parts until relationships are clear – breaks down experiences
	Synthesis	Combines elements to form new entity from the original one - draws on experience and other evidence to suggest new insights
	Evaluation	Involves acts of decision making, or judging based on criteria or rationale – makes judgments about

Fig. 1.2 Different levels of thinking processes based on Bloom (1964)

in practice helps me to understand the theories, have the theories predicted the outcomes satisfactorily, if not why, is it due to operating in different physical, environmental and cultural conditions from the original research? What are the conclusions in a general sense, what can be concluded about my own specific, unique, personal situation or ways of working? and possible ways for improvement. I also had to think about the individuals who influence my choices and lead me into a particular direction in the many cross roads I had to navigate worldwide.

1.2 Influences and Career Evolution

I grew up watching the Baba Qur Qur fires in Kirkuk's oil fields particularly during the summer months when we all slept on the roof, my family home was a few Kilometres away from the headquarters and we could clearly see the flares lighting up the night sky with that unmistakable orange colour from our roof top. This was the start of my boyhood ambition to become a geoscientist.

After sitting my Baccalaureate during 1976, I applied to study Geology and was granted a place in the Department of Geology, University of Baghdad. I graduated with a B.Sc. degree in Geology during 1979/1980 (Fig. 1.3). My interest in Geosciences deepened through fieldwork particularly when theory managed to explain the geomorphology, structural geology and sedimentology of visited sites

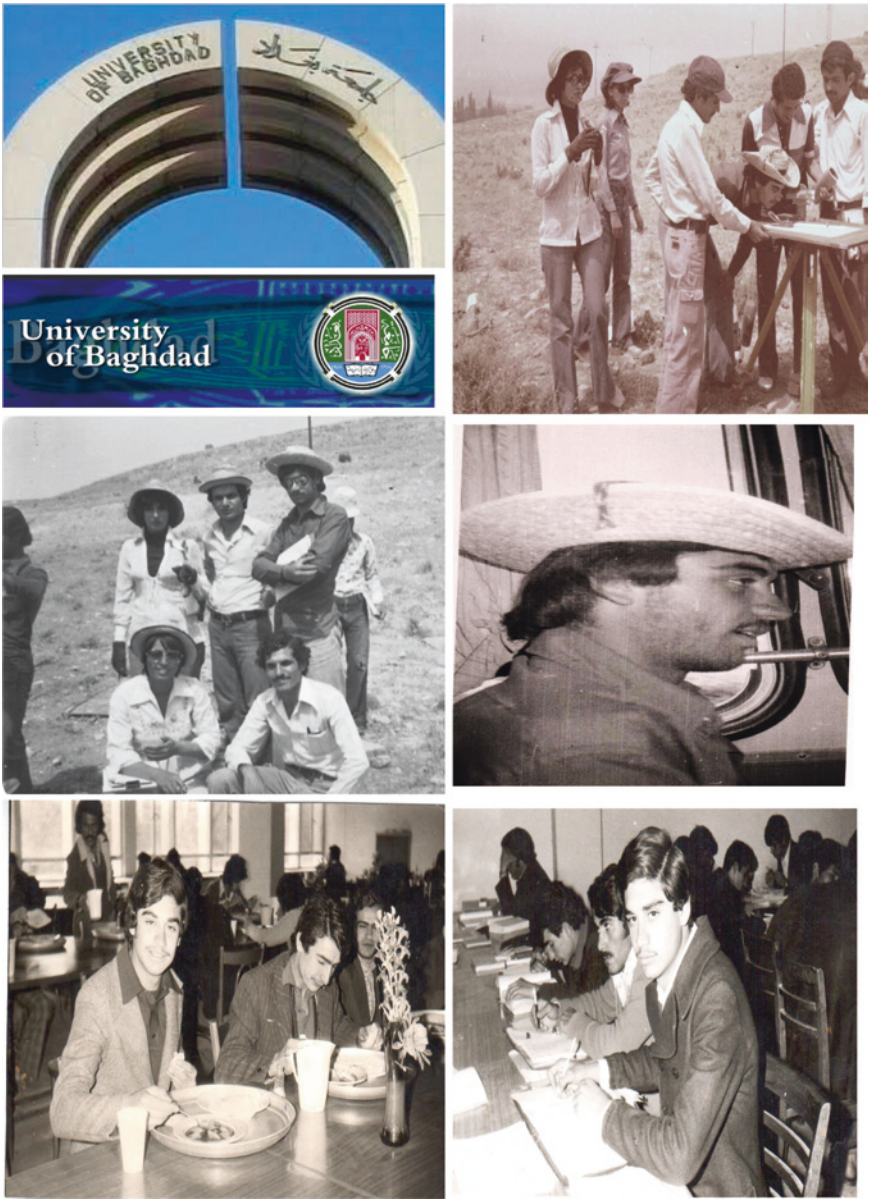

Fig. 1.3 At the University of Baghdad during the B.Sc. years, 1976–1980

and during the final year I became known amongst my peers and lecturers for my improvisation and imagination, not always justified, in solving and explaining various geological phenomena based on field evidence and aerial photographs.

During the following summer Kirkuk was subjected to a series of frightening earthquakes, something that had not happened in living memory, I learned later it was caused by induced seismicity due to injecting water into the oil wells, this captured my imagination. It is perhaps this event, more than most that inspired me, as a young geoscientist from Kirkuk to start thinking about the environment as a system, I started to read and learn about the holistic approach to natural resource management and development as well as the impacts of human actions, the exchanges with the environment and the consequences for society, in other words, to become a geoscientist with a passion for the environment.

This event prompted me to contact the senior scientist in seismology in the Middle East, at that time, Professor Salih AL-Sinawi at the Department of Geology, University of Baghdad and I expressed my interest in reading for an M.Sc. in Seismology. Fortunately, I was offered an opportunity to work under the supervision of Professor AL-Sinawi on a project focused on the potential induced seismicity generated by the water column and volume after filling up a newly established reservoir behind a Dam in Iraq. The project was entitled "*Microearthquake Monitoring of the Hemren Dam Area*". It involved a continuous recording of seismicity for 4.5 months, analysing these records, modelling and data analysis. Historical seismicity was also examined. The outcomes managed to successfully relate background seismicity in the area to tectonic forces and geological formations. Additionally, the induced seismicity was associated with the level and residence time of water in the reservoir. Recommendations to operating the reservoir safely and to the seismic code of the area were made. I obtained my M.Sc. during 1984 with a First Class grade from the University of Baghdad.

During October 1985, I was offered and accepted the post of *Geophysicist and Exploration Party Manager Assistant* by the *Exploration Division in the Iraqi National Oil Company*. Here, after a brief period of training, my duties included supervising all scientific aspects from planning to production and quality control as well as performing all Geophysical duties in the seismological exploration party at that time it was known as 'Party 11'. I was also responsible for managing and motivating a team of 150 staff working under severe physical and environmental conditions. An enjoyable aspect of the work was the responsibility for identifying suitable sites for locating the mobile exploration party, I had the opportunity to practise using aerial photographs for extracting terrain information and land use/cover mapping to indentify suitable sites for the base camp with reasonable accessible routes to and from the base camp to surveying, drilling and recording field sites. I liked the richness of information it embedded and the relative easiness of obtaining the information in comparison to the trial and error approach, i.e. driving through the desert during the summer months relying on a local guide, some old maps and trying to tolerate temperatures reaching 50 °C on regular basis.

This period despite the challenges was productive as I managed to produce several publications dealing with historical seismicity in Iraq and the seismicity in Hemrin area in Iraq (Alsinawi and Baban 1984; Alsinawi et al. 1985; Alsinawi and Baban 1986a, b; Baban and Alsinawi 1986).

Life was becoming difficult for me during 1985/1986, as for millions of other Kurds and Iraqis not associated with the political regime then; my additional crime was being a Kurd, my names reflecting this fact which seemed to make some people uncomfortable to say the least. Consequently, I, with support from my family, decided to leave the country legitimately through perusing my Ph.D.

Initially I wanted to build on my M.Sc. and pursue a Ph.D. in environmental seismology, however, Professor Al-Sinawi managed to convince me after several discussions that remote sensing was then the new approach and I should be a part of it. After considerations, I became enthusiastic about the idea particularly as it was linking in with my admiration of the information content in aerial photographs. In terms of topic, I was determined to focus on water and water resource management as I remain convinced that water, as we observe now, will become the critical factor for human development and society's well-being in Kurdistan and the wider region.

I managed to obtain several offers to study for my Ph.D. and decided to take up the offer from the School of Environmental Sciences in UEA so I could work with Professor Keith Clayton. Consequently, I headed to Norwich during October 1986.

My Physical removal from Iraq meant starting a new life and becoming an English language student, learning to live on the minimum and working very hard to understand various dialects throughout the UK (not to mention the local Norfolk accent); it took some adjusting to but I managed to successfully complete the requirements and had a satisfactory grasp of the English language to embark on my Ph.D.

At first the integration with other students was difficult as not having good English seemed to equate to not being intelligent. It felt very lonesome in fact, I do recall my first Christmas in England being very lonely, invisible, isolated and desperately wanting to belong. My salvation came through Volleyball; I turned up for the team selection and training session and to my delight I made the University team. This was the turning point, I did not waste time reflecting, and simply embraced it and life became enjoyable, hectic, busy and very interesting. In the process I developed my deep understanding of the English Language, culture, ways of thinking and various approaches to decision making and participatory decision making. Furthermore, I learned that the British some how have developed a vertical scale for time as any action starting at present with ending 'up' at some point in time examples being; ending up, tidying up and so on. This was confusing in the beginning as it did not correspond with my 'horizontal' time scale. Thinking I had managed the language well, I discovered at a later date that almost all 'foreign' students were being caught by the pronunciation of the word 'comfortable' myself included.

1.2.1 Finding a Disciplinary Home

During this period I was searching for a disciplinary home for my interests and was most satisfied when I discovered that Haggett (1975), indicated that geography, which is to me now the foundation of all geo-sciences, deals with a specific location in space and is concerned with the earth as an interactive environment for humans who seek to improve the ways in which space and resources are used and finally "Geography produces local specific solutions and doesn't promote a 'one size fits all' approach". Evans (1975) has aligned the geographical notions of space and place, through landscapes, environment and people, grounded on events and processes through time. Hence, he managed to draw together the substance of geography with history. Gregory (1985) indicated that prior to the 1970s physical geography's progress had been hampered by the expensive necessity for collecting data through field surveys, field monitoring, the need for laboratory equipment and analysis. Then later on he indicated that Remote sensing with its increasing wavebands and platforms can provide physical geographers with economical, timely, frequent and site specific data therefore providing a solution for the problems associated with accessibility to difficult locations and to manage data collection issues from varied data sets, particularly volumous data including remotely sensed data; data processing and analysis. He refers to GIS as the relevant technology which also assists with fostering an emphasis upon the integral character of the physical environment.

These thoughts provided me with a great degree of comfort and confidence that my chosen field was the answer for dealing with data shortages and examining geo-based issues at different scales and timeframes. Although, this was very appealing, I resisted being associated with 'geography' at first, as geography in my 'old' world meant lists of capital cities, population density and GDP's.

I remained convinced that the holistic approach to science and decision making was the way forward as to my mind, even then, people, location and environment are the essential ingredients for life, hence, I was impressed by the ecological hypothesis of Gaia, formulated by James Lovelock, which views the Earth as a single organism and proposes that the biosphere and the physical components of the Earth are coupled together to form a complex interacting system (Lovelock 1960). This system is proposed to function in such away to preserve suitable conditions for living organisms on Earth. It is interesting to note that the hypothesis was not taken seriously until 1975, when things changed due to an article in the New Scientist and the publishing of a version of the hypothesis as a popular book entitled; *The Quest for Gaia*.

I was delighted to come across Park (1997) and to learn that he was writing about the usefulness of the systems perspective for our understanding of how the environment functions. Also how human exploitations in terms of misuse of natural resources and disturbance of natural environmental systems are pushing the Earth to the limits of its carrying capacity. In addition, Cooke and Doornkamp (1978), in their text; *Geomorphology in Environmental Management, an Introduction*, gave particular shape to my searches and provided a conceptual and practical framework that has subsequently guided much of my applied work in this area. I was also impressed by LO (1986) through his text entitled "Applied Remote Sensing", particularly the geo-based environmental case studies presented. He provided a thorough understanding and evaluation of various techniques/approaches available and recommendations for selecting a particular approach under the constraints of the data available. Furthermore, he managed to explain and demonstrate the potential for extracting both metric and descriptive environmental data.

The combined effect of these discoveries prompted me to find ways in which to breathe intellectual life into a collection of ideas centred on location, people and the environment. They provided me the intellectual structures with which to examine my ideas. All of these forward looking people brought their own perspectives to the issues of geo-based environmental challenges and invariably introduced the nexus between location, people and the environment; hence ultimately manage Geo-based challenges. While not pretending to present a fully inclusive listing of all influential texts, this short list represents some of the important influences on a young geo-scientist who was interested at this time in the evolution of the interactions between people and the environment both spatially and temporally.

Whilst in the earlier literature, the terms "Remote Sensing", "GIS" and "Geoinformatics" were probably rarely, if at all, mentioned in the texts, they did provide some of the foundation of what was to become the discipline of Environmental Geoinformatics. This is the discipline I was to become thoroughly involved in as a research academic. In fact, these disparate influences provided an intellectual context that has allowed me to marry my interests in both the geo-sciences and environmental sciences. All, inevitably, reinforced my sense that a unifying element in all these is the fundamentally geographical concept of location. It has, thus, been around the concept of *location* that my work has progressed.

In 1988, I started to work on my Ph.D. supervised by Professor Keith Clayton examining Geo-based environmental issues using remote sensing. My thesis was entitled "*The Derivations of Hydrological Variables Including Soil Moisture from Satellite Imagery*". This employed Landsat imagery and microcomputers, image processing techniques and data modelling for extracting and analysing information from a variety of hydrological fields such as bathymetric mapping, thermal pattern detection, water quality, water circulation, water trophic state index and soil moisture. I gained my Ph.D. in 1991 and my D.Sc. in 2011.

1.2.2 Employment and Progression

Since obtaining my Ph.D., more than 24 years ago, I have been in full time employment, first at the School of Environmental Sciences, University of East Anglia, UK. as a *Research Associate*. Subsequently, I was promoted to the post of *Senior Research Associate*. My duties included; categorising different urban patterns in coastal regions, estimating natural and defended rates of erosion and contributed to calculations of resulting economic losses and developing coastal zone management scenarios. I was also involved with another project and was responsible for analysing solid geology and relief information for selected parts of the UK and formulating the data for input into specialised databases.

I joined Coventry University, UK in September 1992, initially as a *Lecturer in Physical Geography* and, from September 1993, as a *Senior Lecturer in Physical Geography* (Fig. 1.4). Here, I had full academic lecturer's duties: developing a GIS Undergraduate degree and an MRes degree in GIS, undergraduate and postgraduate teaching and project supervision; unit and course management and coordination; conducting and managing a growing research programme, including several international projects; contributions to university administration and governance; consultation and other public contributions.

I was part of a team organising and managing the Tunisia's field work for final students. Fieldwork as training and a professional activity required identifying learning outcomes and planning activities to realize these outcomes through field observations as well as ways of assessment. I found cultural preparation of students and supervision to be a crucial element in the process and this included levels of supervision required for each activity taking into account the type of activity, size of the group and their experience. Furthermore, when a third party partner organisation is used they must provide appropriate health and safety documentation and any other requirements (e.g. specific personal protective equipment) for the activities (Fig. 1.4).

Whilst at the University of East Anglia and Coventry University, my research was partly focused on water resources through using Remote sensing and GIS to deduce physical characteristics (Baban 1993a, b, c, 1994), management (Baban 1998a, b, 1999a, b, 2000; Baban and Luke 2000) and the possible impacts of activities associated with development on land based and coastal aquatic environments in the UK (Baban 1995, 1997), then the Caribbean (Baban and Jules-Moore 2005; Al-Tahir and Baban 2005; Al-Tahir et al. 2006) and finally in Australia (Pathirana and Baban 2008; Baban et al. 2008a; Akumu et al. 2010a, b, 2011). Furthermore, I explored various environmental aspects of soil science such as soil nitrates and magnetic susceptibility of top soils (Wade et al. 1996; Dearing et al. 1996; Hay et al. 1994, 1995, 1996, 1997; Wade et al. 1995), involving some of my postgraduate students. Other research interests included investigating the potential for developing and implementing GIS-assisted suitability studies such as investigating and recommending possible sites for locating potential landfill sites in the UK (Baban and Flannagan 1998), Jordan and, later, the Caribbean region (Baban 2004a, b, 2006) as well as Wind farms, in the UK (Baban and Parry 2001) and, later, the Caribbean region (Baban 2004b). I was also, through another Ph.D. project, involved in; developing water resource management and planning strategies for two sites on the Langkawi Island in Malaysia; using field based techniques, environmental remote sensing and GIS for identifying suitable sites for locating two dams on the selected catchments (Baban and Wan-Yusof 2003) as well as establishing and testing various water resource management scenarios to effectively manage the dams (Baban et al. 2003a) (including minimising soil erosion, reducing siltation rates in the dams and harvesting sufficient water for projected increase in demand due to tourism). This Ph.D. project also motivated me to investigate biogeographical and conservation problems, such as natural and semi-natural habitat loss, including deforestation and land degradation, using field based techniques and Geoinformatics, first in the UK (Moran et al. 1996, 1997), then in Malaysia (Baban 2001a, b, Baban and Wan-Yusof 2002; Wan-Yusof and Baban 1998), and later the Caribbean region, (Baban 2003, 2005, 2009a, c; Chinchamee et al. 2006).

The Lectureship at Coventry University was my first full time post as an academic teaching in English to English native speakers and made me deal with the issues of public speaking and time management.

Fig. 1.4 My post, Research Unit and Tunisia Fieldwork with Coventry University Colleagues and Students, 1992–1998

On reflection, I note that this period was very productive as I managed, with help from colleagues, to supervise and graduate 3 Ph.D.'s, 7 M.Sc.'s and over 80 final year undergraduate projects in topics ranging from body-piercing (cultural geography), to modelling hydrological catchments. Furthermore, I managed to establish the *Geographical Information Systems and Remote Sensing Research Utility* (GRRU) *Group* GRRU at Coventry University and developed one of the first GIS Undergraduate degrees and MRes degrees in GIS within the UK Higher Education System.

I was also successful in establishing productive international research collaborations. For example my work with Al al-Bayt University in Jordan lead to successfully organising a bi-national conference in Jordan which developed into my first, co-edited book (Baban and Al-Ansari 2001) on water resources management in the Jordanian Badia Region. It also lead to a funded Higher Education Link between Coventry University, UK; AL al-Bayt University, Jordan and the Badia Research and Development Programme in Jordan through a number of activities including a Ph.D. research project focused on examining the impact of agricultural practices on groundwater quality using Geoinformatics. In addition to many productive and functional professional and personal relationships, these activities produced several publications (Baban and Al-Ansari 2001; Baban 2000; Baban et al. 2003b; Al- Adamat and Baban 2004; Al- Adamat et al. 2004; AL-Ansari and Baban 2001; Baban 2001, 2008b). In order to satisfy my curiosity in terms of the learning processes, I attended a programme in Teaching and Learning in Higher Education and, having completed all the requirements was awarded a Postgraduate Certificate in Teaching and Learning in 1995 from Coventry University, UK.

I moved to the University of the West Indies (UWI) during September 2000 to take up my *Professorship in Surveying and Land Information* in the Faculty of Engineering (Fig. 1.5). There, I was the only Professor in the Department until my departure during December 2000, hence, I provided leadership and became involved in developing new courses and teaching at undergraduate and postgraduate levels, motivating colleagues and energising research within the Department/Faculty and attempting to define focused research areas at the campus level.

In 2004, I was offered the post of *Dean/Chairman, School of Graduate Studies and Research* at the University of the West Indies (Fig. 1.5) with a mandate to expand and enhance the quality of graduate education and promote the University's international reputation for quality research performance and productivity. My approach for realizing this challenge was primarily guided by the University's mission, regional needs, student demand and employment trends, analysis of current postgraduate programs as well as connectivity and sensitivity to stakeholders' expectations and needs. Based on this information some objectives and strategies emerged and I managed, with assistance from my team, to develop and implement a proactive research strategy.

At the University/Campus level, the *Dean/Chairman, School of Graduate Studies and Research,* a *Special advisor to the Pro V C (Research) and the Campus Academic Board Representative, Board of Graduate Studies and Research*. Therefore, I had responsibilities for management, policy development and reporting to the Campus Principal and Pro VC Research and Pro VC Graduate Studies, furthermore, I was responsible for managing graduate students and supervisors; reviewing, formulating and implementing relevant polices; managing

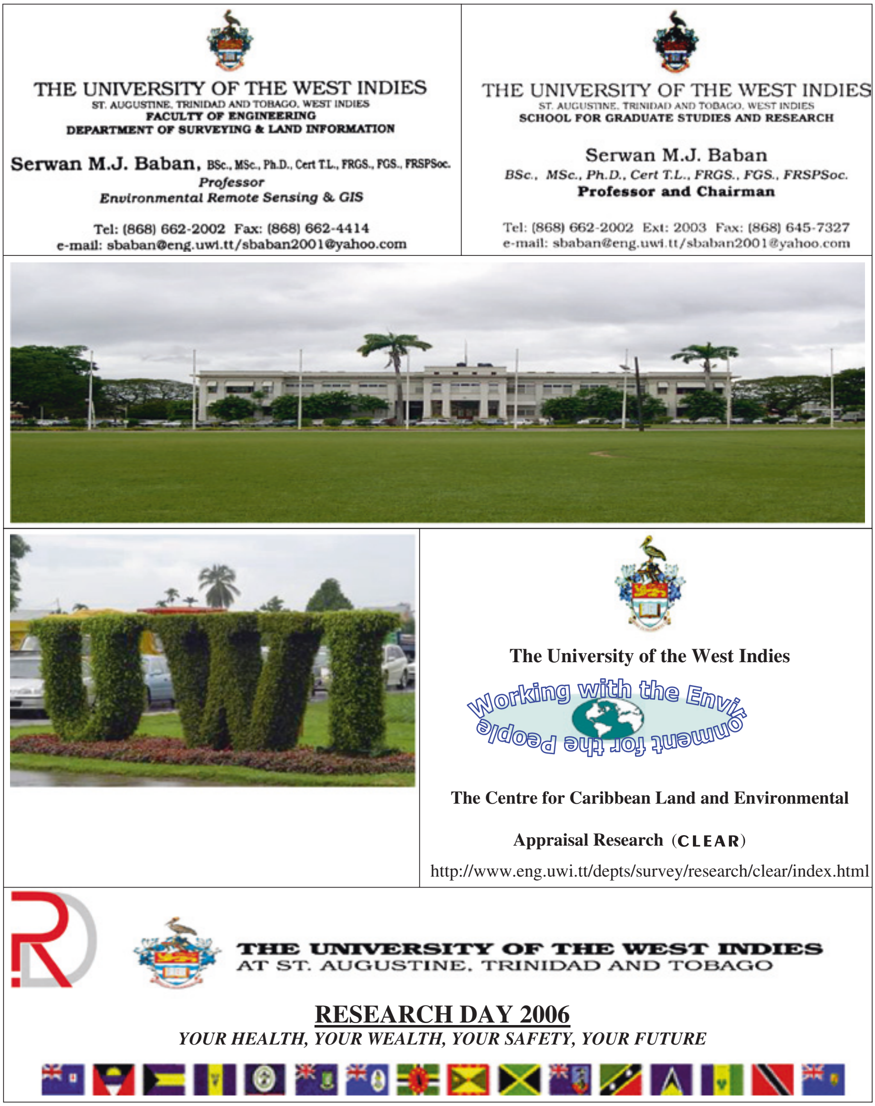

Fig. 1.5 My posts, Research Centre and Research Day 2006 at the Univerity of West Indies

scholarship awarded by the University and externally; guiding and advising individual graduate students and supervisors. I was also chairing graduate-studies committees including: Campus Committee for Graduate Studies and Research; Campus Committee for Research and Publication

Fund and Campus Disciplinary Committee. Finally, I had responsibilities for promoting graduate studies both within the University and externally; identifying potential sources for funding and managing effective relationships with research funding agencies, industry bodies, stakeholder groups and other relevant communities.

My other responsibilities at the Campus level included; Coordinator, Campus Environmental Research Network; Member, Campus appointments Committee; Member, Campus Committee responsible for establishing a school for Environmental Science; Member, Committee for the Rationalization of Environmental Programmes; Member, Campus Academic Board of the St. Augustine Campus. I was also the Director and Founder of the *Centre for Caribbean Land and Environmental Appraisal Research* (CLEAR). CLEAR is a Campus wide research centre, located in the *Office of Research* and reports directly to Pro Vice Chancellor of Research at the University.

At the Faculty level, I was a *member of the Faculty Advisory Committee on Accreditation, the Faculty Committee on Assessment and Promotion, the Academic Board Faculty of Engineering, and Dean's Representative on the Research Degree Sub-Committee.* I was promoting, coordinating and leading research activities in the Faculty of Engineering through *chairing the Research Energising Committee* and being *a member of the Publication board for the West Indian J. Engineering*.

At the Departmental level, I had teaching, research and administrative responsibilities as the professor of Surveying and Land Information. Furthermore, I was the Coordinator for the *M.Sc. Program in GIS* and *the M.Sc. Program in Geoinformatics.*

As it was refereed to briefly earlier, I formed and directed the Centre for Caribbean Land and Environmental Appraisal Research (CLEAR) during 2000 to provide information, advice and guidance with the view to form the foundation for the next phase of the economic and social development plan and to, hopefully, influence future development choices in the Caribbean. In terms of mission, the Centre was focused on:

- Supporting and promoting Sustainable Development through advance multidisciplinary research and development in Geoinformatics and geo-based sciences in general and in new relevant technologies such as remote sensing and GIS in particular.
- Identifying the impact(s) of a range of development and human activities on the Environment.
- Proposing a range of operational measures and solutions which may be used to achieve Sustainable Development.
- Providing a framework for promoting research excellence, consultancy and outreach activities in Environment-related fields underpinned by Geo-sciences.

In terms of tangible achievements in Education, the Centre offered several formal and informal courses in geo-based environmental studies including: Short courses in Environmental Geographic Information Systems, Environmental Remote Sensing, Global Positioning Systems, Digital Cartography, and other related areas.

In terms of definite accomplishments in research, during this period, I developed and lead several research areas responding to and, attempting to address specific regional, national and global needs. My research projects included;

- Managing land use/cover, natural habitat loss, biodiversity, conservation and biophysical land units using Geoinformatics. These projects produced several publications (Baban 2001a, b, 2003, 2004a, b, c); Al-Tahir and Baban 2005; Chinchamee et al. 2006, 2008; Baban et al. 2008b, 2009).

- Evaluating the potential impact of global climate change and sea level change on the Caribbean region which produced several publications (Ramdath et al. 2004; Baban et al. 2005).
- Mapping, modelling and managing geo-hazards, landslides and floods, in the Caribbean region utilising Geoinformatics. These activities produced a large number of publications (Baban and Sant 2004, 2005, 2006; Baban 2005; Al-Tahir and Baban 2006; Sant and Baban 2006; Baban and Aliasgar 2007, 2008a, b, 2009; Baban 2009a, b, 2011; Aliasgar and Baban 2006, 2009).
- Coastal zone, wetland conservation and management using Geoinformatics which produced several publications (Baban and Jules-Moore 2005; Baban and Sant 2008; Ramlal et al. 2004; Ahmed and Baban 2004).

I also managed to establish collaboration with colleagues worldwide including; the School of Environmental Sciences, University of East Anglia, UK through a funded project focused on the development of a landslide hazard appraisal scheme for Trinidad. I was also collaborating with the University of Florida, Gainesville through the T-STAR Program, USA which included joint fieldwork in Puerto Rico (Fig. 1.9); Canada Centre for Remote Sensing through a study to monitor landslides in northern Trinidad using newly launched Canadian Satellites; UNEP and the Caribbean Environmental Health Institute through a Global Environmental Facility (GEF) funded project entitled Integrating Watershed Coastal Area Management (IWCAM) and; the Royal Institute of Technology, Sweden by means of a project which developed a strategy to link sustainability, science and education.

I further strengthened my interest in investigating bio-geographical and conservation problems in the Caribbean region, such as natural and semi-natural habitat loss, including deforestation and land degradation, using field based techniques and Geoinformatics. I chaired a research group examining the ‘conditions and trends in the Northern Range, Trinidad’ as a part of the *Millennium Assessment* in the Caribbean Region. This work involved developing strategies and action plans in partnerships with local communities and NGO’s. This effort was awarded the prestigious *Zayed International Prize for the Environment* in 2005. I have also worked towards developing a Marine Park in Tobago in partnerships with local communities, NGO’s and Tobago House of Assembly.

My research achievements also included developing several papers to energise research, organising an Annual Research Day (Fig. 1.5) to showcase the universities capabilities, organising a Campus wide research retreat. In addition to developing a series of workshops to stimulate research and research productivity, this led to developing my third edited book entitled, *Research, the Journey from Pondering to publishing’* (Baban 2009d). This book was published during 2009 by the University of the West Indies Press. This book was well received, nominated for a number of awards and won the University of the West Indies Press for the ‘Best proposal in Environmental Studies, 2006’, receiving an award, which carried a cash prize and a plaque to commemorate the occasion.

On reflection, this period was very productive as I managed, with help from colleagues, to successfully supervise and graduate 3 Ph.D.’s, 5 M.Sc.’s and 30 undergraduate projects, completed several significant research projects, revised and directed the M.Sc. in GIS Degree and developed and directed the M.Sc. in Geoinformatics. Furthermore, I participated in establishing as well as serving as member of the editorial board for the Asian J Geoinformatics, the International Journal of Geoinformatics and the International Journal of ZANIN. Furthermore I took the lead on revising and then serving as a member of the editorial board for the West Indian Journal of Engineering. Finally, I managed to organise and facilitate a regional workshop on; Enduring *Geohazards (landslides and floods) in the Caribbean Region,* in Trinidad and Tobago during 2004. This evolved into my second Edited book which is entitled; *Enduring Geohazards in the Caribbean Region, Moving From the Reactive to the Proactive* (Baban 2008d). An achievement I am particularly proud of is that my work on Geohazards has influenced decision making at the national level, leading to reforms in planning hillside development in Trinidad and Tobago and I was invited to serve as a technical member on several national committees some of which involved the Prime Minister and ministers with responsibilities for the environment, planning and development in the region. I was privileged to have experienced some extraordinary sights in the region such as Atlantis City in the Bahamas, Richards Shark and Bake in Trinidad, Leather Back Turtles, the pitch lake in Trinidad and several significant religious sites in Trinidad (Fig. 1.6).

The position in the Caribbean was very enjoyable and held promises for further progression, as I was being told consistently by senior management, however, during this period the crime and particularly violent crime, rape and kidnapping for ransom has increased due to the rapid wealth generated by the production of oil and gas in Trinidad and Tobago as well as the geographical location of these island states.

This problem came into sharp focus once a neighbor was kidnapped, hidden in the forest and kept in a hole for weeks. Once, released, he was a broken man and constantly afraid. The degrading crime situation meant that the possibility of subjecting my family to the risk of crime was increasing on daily basis, naturally the family's well-being came first, hence, our decision to sadly leave the Caribbean. This proved to be a wise decision since, one month later, the daughter of a colleague and a senior figure was kidnapped. Having since, lived and worked in many parts of the world, I should indicate, that the Caribbean was without hesitation, the best place we lived in, the people were very generous and warm, the food was amazing and the beaches were a dream. Unfortunately, this paradise was spoiled by a minute number of criminals.

During 2007, I joined Southern Cross University (SCU) in Australia, as the *Professor of Environmental Geoinformatics and Head, School of Environmental Science and Management* (Fig. 1.7). After a period of observation and acclimatization the country and the work culture and ethics in the University. The need for leadership and for change was evident; the senior management agreed with my conclusions and supported my fledgling plans. I, through a collaborative process, developed and implemented a transparent, inclusive management model to handle the core areas of teaching, research and University service within the School. I also established a strategy group for the School to develop ideas for sustainability

Fig. 1.6 Some extraordinary experiences and sites in the region; Atlantis City in the Bahamas, Richards Shark and Bake in Trinidad, Leather Back Turtles, the pitch lake in Trinidad and several significant religious sites in Trinidad

including a clear brand/identity, developing focused team based research areas, a practical mentoring system, rationalising course offerings and teaching load. I moreover implemented several policy papers to manage both routine and strategic issues within the School. I am happy to report that the School became financially secure; in fact it had a surplus for the following year, an event that had not occurred for several years and the student intake rose, against the national trend in Australia.

In order to continue with my research and develop new relevant areas to Australia, during 2007, I established the *Centre for Geoinformatics Research and Environmental Assessment Technology* (GREAT) (Fig. 1.7). This centre was aiming to:

- Develop and lead a multidisciplinary team, establish national/international collaboration and obtain funding for research.
- Identify the impact of a range of development and human activities on the environment and to propose a range of operational measures and solutions which may be used to achieve sustainable natural resource management.

Fig. 1.7 My post, research centre, fieldwork with students and a visit by Prof Chris Vincent, Dean fro School of Env, Sciences, University of East Anglia, UK

- Lead and promote sustainable development and sensible environmental and natural resource management by means of evaluating the current state of the environment-related fields underpinned by Geo-sciences through collecting,
- analysing, managing and disseminating geo-based information on natural resources and the condition of the environment.

I was satisfied with my performance in this role as my team was established in a short period of time and began to gain recognition in Australia and beyond as evidenced by the increase in postgraduate applications to work in Geoinformatics as well as obtaining several research, consultancy and professional training grants. These included developing an intensive course in GIS for academics from Saudi Arabia, a project on managing coastal erosion issues in Darwin, North Australia; managing climate change issues in the wetlands of New South Wales; developing coral reef habitat based indicators for climate change in Australia and developing a Geoinformatics based early warning system for floods in Trinidad.

Achievements during this period also included several publications in the fields of wetland management (Akumu et al. 2010a, b, 2011) and climate change (Pathirana et al. 2007; Baban 1997), Coastal benthic habitats (Baban et al. 2008b) and coastal erosion issues and management (Baban and Cannisus 2008; Jones et al. 2008).

Furthermore, I was invited membership of the Scientific Committee, *Current Trends in Remote Sensing and GIS Application*s a Conference held at the Indian Institute of Technology, Kharagpur, February 15–17, 2007, West Bengal, India; invited participation and presentation in the *United Nations Regional UN-SPIDER Workshop: Building Upon Regional Space-based Solutions for Disaster Management and Emergency Response for the Pacific Region.* This was held Suva, Fiji, 16–19 September 2008 (Baban 2008a, c); invited membership of the Scientific Committee, *the 2nd International Conference of GIS/RS in Hydrology, Water Resources and Environment (ICGRHWE'06) and the 2nd International Symposium on Flood Forecasting and Management with GIS and Remote Sensing (FM2S'06)*, co-organized by Sun Yat-Sen University of China, Bristol University of UK and Kyoto University of Japan, this conference took place during September 17–23, 2007 at Guangzhou, China; invited membership of the International Scientific Committee, *the International Groundwater Conference, Groundwater India 88*, co-organized by University of Rajasthan, India, Planet Earth and UNESCO. It was held during March 19–22, 2008 at the University of Rajasthan, Jaipur, India. Furthermore, I was an invited member of the international advisory committee for *the Second International Conference on Geoinformatics Technology for Natural Disaster Management and Rehabilitation.* It was held during January 2009 at the Asian Institute of Technology (AIT), Bangkok, Thailand. I was also an invited member of the international advisory committee and invited Keynote Speaker for *ISA-RC-24- International Conference on Water, Environment, Energy and Society.* This conference was held during June 28–30, 2009 in Firozabad Agra, India.

During this period, I became homesick for Kurdistan, I kept thinking about my extended family, friends, the Kurdish spring, the mountains and the delicious Kurdish food. Once, I turned 50 years old, I almost became infatuated with going 'home'. The possibility of having Australia as my permanent home and when demising, the mixing of my body with anything other than Kurdish soil was at that time very disturbing to me. I started to seek opportunities at Kurdistan, one day, whilst examining the Times Higher Education Jobs on line, I noticed, an advertisement for a global search for a Vice-Chancellor for the University of Kurdistan Hawler in Erbil. I sent in my completed application form and waited patiently and hopefully.

Fig. 1.8 My post and some activities at UKH 2009–2012

I was shortlisted and invited for an interview. The international appointing committee and interview panel consisted of senior academics from Lancaster University, UK; University of Pennsylvania, USA, the Kurdish Institute of Paris and local universities as well as a member of the Governing Board and the committee was chaired by the Chairman of the UKH Governing Board. During August 2009, I was appointed as a *Professor of Geoinformatics and the Vice Chancellor* (Fig. 1.8) for the University of Kurdistan-Hawler (UKH), Federal Region of Kurdistan, Iraq.

In order to continue with my research and develop new relevant areas to Kurdistan and the wider region, during 2009, I founded and directed *the Geoinformatics Institute for Future Threats to Sustainability* (GIFTS) (Fig. 1.8). GIFTS was founded at the University of Kurdistan Hewler to provide advice on, investigating, mapping, monitoring and managing processes and issues impacting Sustainable Development in Kurdistan and the wider region. GIFTS is committed to informed decision making, contributing to the next phase of economic and social development and in influencing future development choices for the future of Kurdistan and the wider region. More specifically it aims to;

- Advance multidisciplinary research and development in Geoinformatics and geo-based sciences in general and in new relevant technologies such as remote sensing and GIS in particular.
- Provide the infrastructure to foster interdisciplinary research in Geoinformatics, Sustainable Development and Environmental Geo-based solutions.
- Assist with expanding and strengthening Geoinformatics, Environmental and Geo-spatial research, consultancy and outreach at all levels.
- Foster capacity building and encourage the dissemination of research findings.
- Actively involve the organization of local, national and international conferences.
- Strengthen environmental and geo-spatial education.
- Ensure scientific and technological solutions are brought to bear on problems.

In terms of research outputs and publications, I have managed to produce publications dealing with the role of government Higher education institutions in the nation building process (Baban 2011a, 2012c), sustainable development (Baban 2012a), establishing independent international universities (Baban 2012b).

Overall, I am proud of my performance in this role as the University of Kurdistan-Hawler was consistently ranked within the top 5 Universities in Iraq during my Vice Chancellorship. Furthermore, the University was established as it has managed to successfully graduate two cohorts, developed significant international collaborations with British Universities including the University of Leicester and University of London and Brighton Universities. In addition managed to consolidate a successful Student Exchange Programme in Politics and International Relations with the University of Amsterdam.

In addition, I introduced External Examiners to ensure the quality and standards of the examinations, developed a process for validating new programs to ensure that the academic portfolio meet the highest international standards and at the same time address the needs of Kurdistan, focused on matching graduates to market needs, as *Graduate employability* is a priority, hence this year we also organized Self awareness, CV Preparation and Interview Skills workshops followed by a career fair for our graduates. Furthermore, I managed to develop and implement two new Masters Programmes in Business Management and International Studies, Staff members obtained higher Academic qualifications; two completed their Ph.D.'s from international universities, 5 obtained their PGCET in

Teaching and learning from the University of Brighton, UK, Two staff members attended Training in the UK on Supervising Ph.D. students and projects.

Quite unexpectedly I was approached and asked to become a 'Technocrat Minister' in the regional government, I considered this a great opportunity to serve at a much bigger platform and agreed after a brief period of consultation with family and friends, consequently, I was appointed Minister of Agriculture and Water Resources in the seventh cabinet, on 5 April 2012 (Fig. 1.9).

Historically, Kurdistan has been a region of agricultural produce and a source of various crops such as wheat, chick-peas, apple, sumac, peach, grapes, and many other products. It has been shown that much of the agricultural produce from Kurdistan was exported to neighboring countries. During the 1960s, 1970s and 1980s, Kurdistan exported crops to the centre and south of Iraq.

The Kurdistan region is rich in water resources with five large rivers that run through it. These include the Khapoor, Great Zab, Little Zab, Awaspee, and Serwan. The total annual water flow capacity stands at 30 billion cubic meters. About 59.8 % of the water sources of the rivers mentioned is from Kurdistan, and 40.2 % is sourced outside of Kurdistan. The total arable land in Kurdistan is 1,535,794 hectares. If the water is used properly, it could irrigate the entire land instead of the 11 % it currently irrigates. In addition to the five rivers mentioned above, Kurdistan has springs, groundwater, and rain water from the annual rainfall of 8 billion cubic meters. However, most of it is wasted as it falls into the land and valleys without being used.

The conflicts and years of unrest in the region in the past paralysed the agriculture sector and destroyed its infrastructure up until the uprising of 1991. From that date until 1996 farmers tried to improve this sector but the United Nations Security Council 986 Resolution of Oil for Food had a negative effect on Kurdistan's agriculture and water resources sector. Kurdistan went from being a producer to a consumer. The Kurdistan Region is also affected by the global climate change. Thus a radical reform is needed for the entire sector. But before doing that, changes are needed within the vital areas of production including, management, training, legislation, guidelines and methods of work.

As a Minister I was tasked with providing the essential leadership and management to realise food and water sufficiency and ultimately security for Kurdistan region. Effectively, I was also charged with reorganising and restructuring the ministry and the workforce to *match function with form*, to develop and implement relevant policies and give the guidance needed to meet the food and water needs of a new and developing nation. Given the way the region has evolved and the political systems which have developed, I soon realised that achieving these objectives would require a political consensus and the cooperation of all parties involved; the Parliament, the political leadership, the expert authorities, farmers, and the people of Kurdistan. Having consulted widely and also reflected on my own experience, I developed a view that rehabilitating and improving agriculture requires focusing on staple products and making available, from local producers, to citizens a healthy diet based on internationally approved standards. In addition to making water available based on an understanding of the geopolitics, the impacts of climate change, and development and population growth in the region.

Fig. 1.9 My post and some activities in the Ministry of Agriculture and Water Resources

However, as a priority, there was a need for thresholds and constants to build priorities and the decision making process upon, after a period of intensive consultations and brain storming, the collective in the ministry has agreed to be guided by the following principles and values; Sustainable development; Economic Integration through considering Kurdistan region as one management and economic unit; Public interest; nation building; collective, process based and transparent decision making; building processes and systems; Merit based Performance/promotions; successive planning; continuous mentoring of staff.

This was followed by developing the Roadmap based on consultative process. The review process for an existing plan and consultations with all stakeholders, lead to the development of two sets of priorities. First, Immediate Priorities, these dealt with preparing the Ministry and the Workforce to deliver the Strategic Priorities. In real terms this involved dealing with issues such as; developing and managing the workforce, Structure, operations and working practices within the ministry. Secondly, Strategic Priorities, theses were defined as achieving food and water self-sufficiency and security; a holistic approach for management, provide sustainable sources of water, continues support to productive farmers and link this support to productivity, support applied research, managing ongoing agricultural land issues; encourage and promote the involvement of the private sector. To date, these activities have produced publications, conference presentations and several keynoting opportunities (Baban 2011a, 2012d, 2013a, b, c, d, e, f).

Finally, my career was influenced by many key individual academics. Briefly, at the start of my career, I was being influenced, in particular, by Geoscientists, from the University of Baghdad, who had a focus and an understanding of the location and the environment, and for whom I owe a special debt of gratitude. Most notable are Sahil Al-Sinawi (my mentor and M.Sc. supervisor), Nadir AL-Ansari (currently a research collaborator) and Thea Al-Rawi. At Coventry, UK, David Smith (mentoring me through the maze of the British Higher Education System), Ian Foster (a strong supporter of my work and research collaborator), John Dearing (a supporter and co-supervisor on a Ph.D. students project), Brian Ellbery (reinforcing the importance of methodology and systematic approach to problem solving) and Andrew Millington. In addition to these was the then staff at the School of Environmental Science in UEA including Keith Clayton (my Ph.D. Supervisor), Chris Vincent, Tim O'Riordan, Brian Moss, Tim Atkinson, Keith Tovey and Andrew Lovett. I also appreciate the support from friends Marcus Armes, Phil Newton and Simon Gerrard to name but a few. It would be fair to say that these individual academics, more than any, provided me with the building blocks of a career that has included research on many aspects of Environmental sciences. Their various interests and expertise can be found in direct lineages through my work, in particular work addressing issues of hydrology/hydrology, water resource management, Geohazards, land use/cover and biodiversity, sustainable development and climate change. Their combined influence may help explain my enduring geographical and environmental emphasis and the focus on the holistic approach and multidisciplinary approach.

While outlining this progression of influences, I am reminded of the role of self-reflection, analyses of career and work (Cloke et al. 1994) especially Cloke's own reflections of the interactions between relationships with peers and teachers, personal views and philosophies, and the directions his academic and intellectual work over several decades, provides a useful and applied model. While I do not intend to emulate their approach in this chapter, to some extent I will follow their lead and highlight other significant relationships and influences. In the following chapters, I will outline the academic and intellectual progress of my various researches, and it should be taken as read that these two accounts overlap. To this end, I record here the probably typical stages of an early career researcher, as I have experienced it.

1.3 Developing a Research Focus and Expertise

In the most basic sense, my research has developed from my own curiosity to discover, being able to adapt to new environments and seeking practical solutions for local problems and from my desire to develop teams and to share my findings with other interested people.

As a lecturer-researcher myself, I have been motivated to undertake research that will be of use to practitioners. Here, I was very aware of the need for on-going research into Geosciences, Environmental Science, Geoinformatics (Environmental Remote Sensing and GIS) as well as Management and Governance and my research efforts since then have been motivated by my desire to add to that body of research knowledge.

My multi-disciplinary Geo-based research and my career which took me worldwide, though unexpected, it lead into a systematic and organic developments. I gained working experiences in Arid/Semi Arid (Iraq, Tunisia, Morocco, and Jordan), Temporal (UK) and Tropical environments (Malaysia, the Caribbean region, Indonesia and Australia).

1.3.1 Research Interests

1.3.1.1 Evolution of Research

In this section, I describe the stages through which my research has developed to reach this focus. I commenced with enrolment in an undergraduate degree at the University of Baghdad, lasting from 1977 to 1979 (Fig. 1.3), in which I sought to find a suitable home for my academic interests. As indicated above, the Department of Geology became that home, and I believe became the incubating ground for what went on to become what I consider to have been, and continues to be, a fruitful and most satisfying and fulfilling academic career. Graduating from the University of Baghdad with a degree in geology.

I initiated my research work through my M.Sc. degree, in the same Department from 1981–1984 with studies of induced seismicity using Geo-sciences and Environmental Geophysics to examine the possible impacts of the water column and volume in a lake on the seismicity of the surrounding area. Following a period working as a field based Geophysicist which taught me the value of team work, patience, being a good listener as well as being practically minded and result orientated scientist. I soon diverged in interest, and developed research in Environmental Remote Sensing.

I started my Ph.D. with the University of EAST Anglia (UEA) during 1988. My research examined the applicability of remote sensing techniques in various aspects of hydrology, employing Landsat imagery and microcomputers. Image processing techniques and data modeling using new and established algorithms to relate Landsat imagery to ground referenced variables. To allow future portability much of the work was done on a PC using the standard Image Processing Software (PCIPS package). Methods available were reviewed and examined; detecting mapping water depth in lakes using newly established as well as available algorithms; detection and interpretation of water surface temperature and circulation employing thermal (TM6) and reflective and reflective (TM1) bands in three lakes; detection and interpretation of water quality parameters in lakes using various TM bands and band combinations to develop specific algorithms; establishing trophic classifications for lakes using available methods, the Carlson method provided a sound basis for classifying these lakes into three groups using the external load of total phosphorus and its influence on the trophic status of these lakes; classification and water quality parameter detection in an estuarine environment; land cover/use classification and the detection of soil moisture levels using remotely sensed data using published algorithms.

I moved to Coventry University as a lecturer in physical geography (Fig. 1.4). There, under the enthusiastic support of David Smith, then the Professor in geography and Associate Dean (Research), I was allowed to develop a research profile focusing on geosciences, environmental remote sensing and GIS. I must record the keen support I received from some prominent geographers who were central in the areas of my interests. Notable amongst the “welcoming committee” was Ian Foster, David Smith, Hugh Mathews, Tim Mighill, Martin Phillips, John Dearing and Brian Illbery. Collectively, they supported and encouraged this “new chum” to commence a career in geo-based environmental research.

While working in the UK (the University of East Anglia and Coventry University), my research was partly focused on water resource management and the possible impacts of activities associated with development on land based and coastal aquatic environments. Furthermore, I explored various environmental aspects of soil science such as soil nitrates, and magnetic susceptibility of topsoil’s.

Other research interests include GIS based suitability studies through investigating the potential for developing and implementing GIS-assisted criteria in identifying optimum locations for landfill and wind farm sites in the UK, Jordan and later in the Caribbean region. I have also been involved in using remote sensing and GIS for identifying suitable sites for identifying suitable locations for dams in Malaysia as well as establishing and testing various water resource management scenarios to sustainably manage the dams through minimising soil erosion and reducing siltation rates. My career at Coventry was discontinued with the opportunity to take up, in 2000, a permanent position as Professor of Surveying and Land Information at the University of the West Indies, Trinidad and Tobago. At this stage, I must acknowledge Ian Foster, John Dearing, Nadhir AL-Ansari and Andrew Millington who welcomed my geo-based environmental focus into their major fields of research, and with whom I work on a regular basis in an integrated manner. I have, of course, worked with other people, but these individuals are owed a specific acknowledgement.

Whilst at the University of the West Indies (Fig. 1.5), I developed and lead several research areas responding to and, attempting to address specific regional, national and global needs. My research projects included mapping and managing land use/cover and biodiversity, examining the potential impact of global climate change on the Caribbean region and managing geo-hazards. I was involved in collaborative research with Coventry University, UK; AL al-Bayt University, Jordan and the Badia Research and development Program in Jordan; the School of Environmental Sciences, University of East Anglia, UK; the University of Florida, Gainesville, USA; Canada Centre for Remote Sensing; UNEP and the Caribbean Environmental Health Institute; Royal Institute of Technology. I was also involved in investigating natural and semi-natural habitat loss, including deforestation and land degradation in Malaysia and the Caribbean region using Geoinformatics. I lead a team which developed strategies and action plans to sustain Northern Trinidad, in partnerships with local communities and NGO's, as a part of the *Millennium Assessment* in the Caribbean Region. I also developed interests in examining various approaches and strategies developed and implemented by developing countries such as Tunisia, Jordan, Malaysia and Iraq to balance development demands with environmental obligations. Finally, I developed interests in research training, developing workshops to energise staff research and provide guidance for obtaining research grants.

My move to Australia and joining Southern Cross University (Fig. 1.7) provided opportunities to work on coastal erosion issues; managing climate change in the wetlands of New South Wales; and developing coral reef habitat based indicators for climate change in Australia.

The next chapter in my career took me back to my homeland as the Vice-Chancellor/President, The University of Kurdistan-Hawler, Federal Region of Kurdistan, Iraq. I assumed office during 1/08/2009 (Fig. 1.8).

Working in the School of Environmental Science at the University of East Anglia, a research active Geography Department at Coventry University, the responsibility to develop, manage and lead geo-based environmental research as the only Professor at the University of the West Indies and finally working in a School with a focus on the Environment and environmental management at Southern Cross University, the issue took shape. The field of Environmental Geoinformatics fully emerged as my major research contribution over the last two decades. My research in this area had its beginnings in a boyhood interest and ambition and evolved through adapting and responding to needs and challenges in new environments throughout my career. I started my career in Iraq, moved to the

UK, the Caribbean then Australia; each home provided me with a different set of opportunities which I embraced.

Building my profile within this ‘nomadic’ career meant building teams and developing people, something, I have had a very good success rate and I am very pleased about as I feel, in a small way, I am returning the favour to my mentors and contributing to profession through developing the most precious element of them all, people. All my individual projects now involve either collaborative research with academics external to Southern Cross University, both in and beyond Australia, and/or groups of postgraduate research students and undergraduate project students.

As the oldest child of seven in my family, I learned early on that dealing with people is a difficult matter, hence, I developed my own objective approach, which is working for me, it is based on four broad factors. First, I learned to listen carefully, and to see the other viewpoint and provide the necessary help, motivation and mentoring. Secondly, the belief in and commitment to the application of equal opportunity and equality principles. Thirdly, attempting to create a supportive environment for colleagues and co-workers and assisting them with gaining experience and realising their full potential within a team framework. Finally, I believe that self-interest is the lever that will move people and once they can see how dialogue, collaboration and teamwork can serve their interests and advance their cause they will contribute effectively to the process of developing and advancing the Department, School, Faculty and the University at large.

This approach has also helped me with developing and managing multidisciplinary and interdisciplinary research groups and centres. Whilst at Coventry University, I developed and successfully managed the *GIS Remote sensing Research Unit* (GRRU) research Unit. At the University of the West Indies; I founded and directed the Centre for *Caribbean Land and Environmental Appraisal Research* (CLEAR). At Southern Cross University I founded and am directing the Centre for *Geoinformatics Research and Environmental Assessment Technology* (GREAT). At the University of Kurdistan Hewler, I founded and directed The *Geoinformatics Institute for Future Threats to Sustainability* (GIFTS). These centres function well in providing the framework and infrastructure necessary for supporting and promoting team work, productivity and an identity for a group with similar vision and objectives.

As an academic, of course, there are always other paths to tread and, as is documented below, several other interests have intruded into the dominant areas I have outlined above. It is perfectly reasonable that, as a career university academic, matters of teaching and learning become more than just issues of professional development and the betterment of one’s own teaching practice. I have hence indulged in some scholarly activity, researching and publishing on aspects of higher education practice. I have become active in the governance of the university’s core activity.

I found myself drawing increasingly on a disparate range of sources that began to influence my work in this area. For example, I revisited texts from my undergraduate days, working my way through to more current texts. Johnston’s book

(1973), spatial structures, introducing the study of spatial systems in human geography, provided an excellent way forward for a GIS based approach to deal with landscape evolution. They gave me the heuristic device of peeling away the layers of history embedded in the fabric of a landscape, a notion I was later to extend to the spectrum layers embedded in a single satellite imagery. Furthermore, they appealed to me at a time when I was becoming increasingly interested in the ways human kind interact with the environment and how locations will contain evidence of the type and impact these interactions have had on the environment.

1.3.1.2 Current Research Record and Achievements

My aspiration is to understand and learn to manage geo-based challenges within a geographical location, attempt to provide information for effective environmental decision making using geosciences and environmental Geoinformatics and to hopefully assist in creating a sustainable future via developing reliable management options for decision-makers particularly in developing countries.

In terms of publications, I have Authored and Co-Edited Twelve books and *over 200* research and consultancy publications as follows: *Refereed Journal and Conference Proceeding publications* = 101; *Refereed Chapters in books* = **37***; Consultancy and Special Reports* = **34***; Other Refereed publications, Presentations and Abstracts* = **63**.

My research interests focus on developing and employing Geoinformatics (Environmental Remote sensing and GIS) based approaches, mainly to find sustainable solutions, for managing challenges in the areas of geo-sciences and environmental science and ecology (hydrology and hydrogeology; resource management and sustainability including biodiversity and conservation; geo-hazards with a focus on landslides and floods; soil science; coastal zone management and climate change) and development issues including ‘information poverty’, decision making as well as research training and education. I am also interested in Management and Governance.

In terms of conceptual research, I am interested in various aspects of research to assist with managing geo-based issues related to natural resources, environmental and development. These include developing lake management strategies, minimising water related natural hazards, sedimentation, and sediment source tracing in reservoirs and lakes. I have also developed strategies for managing tropical forests using environmental remote sensing and GIS (Malaysia and the Caribbean Region); I have also developed a holistic approach and a research agenda to manage desertification in the Middle East; managing the environment and studying geo-hazards in the Caribbean region. The potential use of remotely sensed tracers within a GIS framework in understanding hydrological processes in catchments. I have also explored the possibilities of using *representative ground truth data* and *retrospective ground truth data* with remotely sensed information to extract and, to supplement information for natural resources, environmental and development related investigations. As cloud cover is a serious problem in the Caribbean region, I have developed and tested methodologies for removing cloud cover from Satellite Imageries by using field based and secondary data sets. Owing to information poverty in the Caribbean, I recently became involved in developing scenarios for modeling some of the possible impacts of climate change on food systems and the environment in the region. Whilst in Australia, I was working on coastal erosion issues; managing climate change consequences in the wetlands of New South Wales; developing coral reef habitat based indicators for climate change in Australia' and developing a Geoinformatics based carrying capacity concept for floods, at the hydrological catchment level, to minimise risk and realise sustainable development in Trinidad. At the University of Kurdistan Hawler, I developed interests in Governance, management as well as improving quality in Higher Education.

1.4 Early Influences and Career Evolution: A Conclusion

Perhaps some of the most important lessons I have learned are to plan carefully, focus on specific questions and issues, consider local conditions, and review the literature and to develop logical and practical procedures to sustainably manage both the daily and long-term challenges. I have learned to be cautious about claiming to have achieved or done more than I have actually done, or of claiming to know more than I actually know as a result of my research efforts. Here I am always reminded of the story of three scientists travelling together to a new province and on the way they see a brown cow standing in a field from the window of the train (and the cow is standing parallel to the train). One scientist declares that "the cows in this province are brown." The second says, "No. there are cows in this province of which one at least is brown." The third and the more established scientist say, "No. there is at least one cow in this province, of which one side appears to be brown."

Formulating clear research problems and sub-problems is not simply an academic exercise. Rather, these problems and sub-problems provide crucial guidance throughout the research process. For example, they lead directly to the development of the detailed framework for content analysis in descriptive studies of compositions or curriculum documents, and to the design of the questionnaire in a survey study. In addition, the problems and sub-problems guide the interpretation of research findings and the reporting of research results as one presents answers to the questions originally posed. While general questions may provide the initial motivation for research in a given area, a specific research problem and sub-problems must be developed to guide the research.

I consider it essential to view any particular research study as part of a larger body of research. I have always attempted to plan my research by building on my own previous work and on the work of others, sharing my results and my research procedures with others, so that as a community of researchers we can gradually test and expand our knowledge base.

Remote Sensing Based Application and Project Development Procedure

1. Identify an application/problem

- Examine the spatial and possible spectral characterises of the features involved.
- Identify the rate of change in the phenomena (Temporal change)
- Decide on the type of remotely sensed data required, i.e. identify the resolutions necessary for the study.

2. Explain why a study is beneficial

e.g. why the Remote sensing will help
For each problem identified, suggest a solution

↓

Basis for gaining approval

3. Develop a methodology to implement (Think about the process and tools required).

4. The proposal solutions ⇨ present different options

Select a methodology

↓

Divide into sub tasks → Define time frames.
Define Resources.

5. Develop a schedule based on the purpose, scope and objectives.

6. Develop a responsibility matrix

- Identify major milestones including deliverables within specific timeframes.
- Responsibility and Accountability

7. Implementation must ensure

- Data quality and suitability
- Cost is monitored
- Stakeholders engaged
- Scope managed
- Prepare documentation

Fig. 1.10 Remote Sensing Based Application and Project Development Procedure

In drawing this chapter to a close, I return to Evan's idea that Geosciences produces local specific solutions and doesn't promote a 'one size fits all approach', which I refereed to previously. In this short statement, he encapsulates for me natural systems and the complexity of spatial and temporal patterns, as much now, three decades into my career, as they did at the start of my career. They bring together

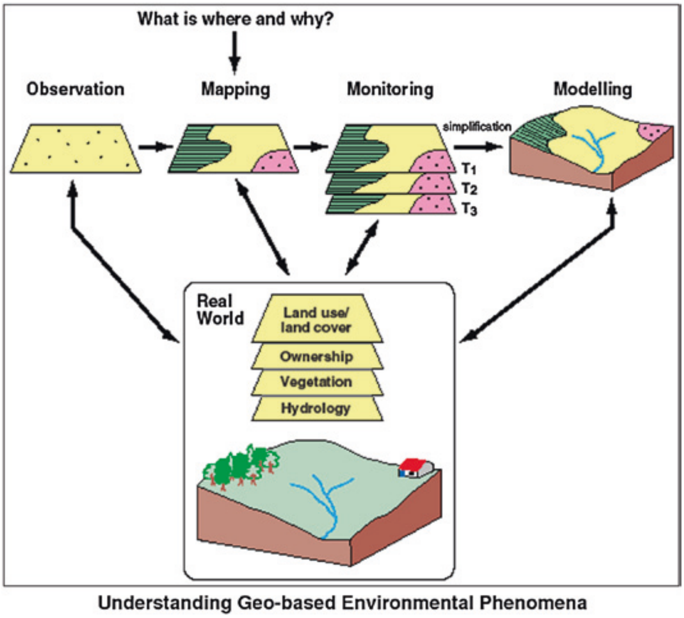

Fig. 1.11 Understanding Geo-based Environmental Phenomena (Baban 2001a)

the human, natural and the physical, and place them into a network of interactions and processes, processes that are inherently time-dependent, and thus highlight the diverse and disparate phenomena that define landscapes, land cover/use distribution and the environment at large.

Evidently, this is not a new observation (Stoddart 2000), and many other authors have examined various aspects of the interactions between people and the biophysical environment, at physical, behavioural and cultural levels (e.g. Crandell 1993; Schama 1995; Ashmore and Knapp 1999; Muir 1999; Head 2000). However, from my own personal perspective, as I revisit these early words, I can see the seeds of the diverse and disparate scholarly paths I have taken over the last three decades. My research areas as a whole are bound by the fundamentally geospatial concepts of location, the environment and people, collectively, they can be described as Managing Geo-based Challenges.

Despite this enduring general interest in the ways in which geo-based environmental scientists are perceived, finding a focus for an active academic engagement with this topic, however, grew out of the necessity for me to evolve and develop relevant research and related teaching as my academic career took me from Iraq to the UK, the Caribbean, Australia and finally Kurdistan region in Iraq.

I have learned that the sustainable solutions are often the outcome of a holistic approach to problem solving which tends to simplify issues, focusing on cause and effect as well as social and local factors, then attempting to manage the factors which have the maximum impact on an issue. Such as asking relevant questions and following tested and approved procedures to develop Remote Sensing Based Applications (Fig. 1.10), or understanding Geo-based Environmental Phenomena (Fig. 1.11).

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Chapter 2
Geo-hazards Science and Management

2.1 Introduction

My association with Geo-sciences came about from being raised in the oil rich city of Kirkuk and being surrounded by oil and gas production and wanting to 'belong' to this world. I managed to gain entry in 1977 and successfully obtain an undergraduate degree in Geology from the University of Baghdad during 1979. It was then; I thought I had found a suitable home for my academic interests. This was followed by an M.Sc. in geophysics and a position with an oil exploration company. My Geo-sciences background was helpful with establishing a profile in the discipline through obtaining research projects and conducting consultancy activities as well as involvement in supervising student projects, in the UK, Malaysia, the Caribbean and Australia.

My research in Geo-sciences based issues has evolved as a response to my active involvement with international research groups and societies, relocations and the need for developing solutions for and managing geo-science based challenges such as floods and landslides in these new countries and locations, I called home for a number of years. For example, when I moved to the Caribbean during September 2000, it was evident that floods and landslides occur frequently and tend to dominate all aspects of life on the Small Island States (Fig. 2.1). Hence, within a year of moving to the region, established a research focus on managing these issues. My approach was founded on developing prediction approaches and progressed based on advancing the *deductive* and *pro-active approaches* for managing the dominant geo-hazards of floods and landslides. In Australia, coastal erosion represents a serious problem; hence, I initiated investigations into coastal erosion with Darwin City Council in North Australia. The sections below will provide details of my research in geo-hazards science and management worldwide.

S. M. J. Baban, *Managing Geo-Based Challenges*, Environmental Science and Engineering, DOI: 10.1007/978-3-319-07380-4_2,

Fig. 2.1 Floods and landslides in the Caribbean region

2.2 Geo-hazards Science and Management in Iraq

I started my research in geo-hazards science and management through my M.Sc. degree in 1981–1983, with studies of induced seismicity using Geo-sciences and Environmental Geophysics to examine the possible impacts of a water column and volume in the Hemren Dam Lake on the seismicity of the surrounding area (Fig. 2.2)

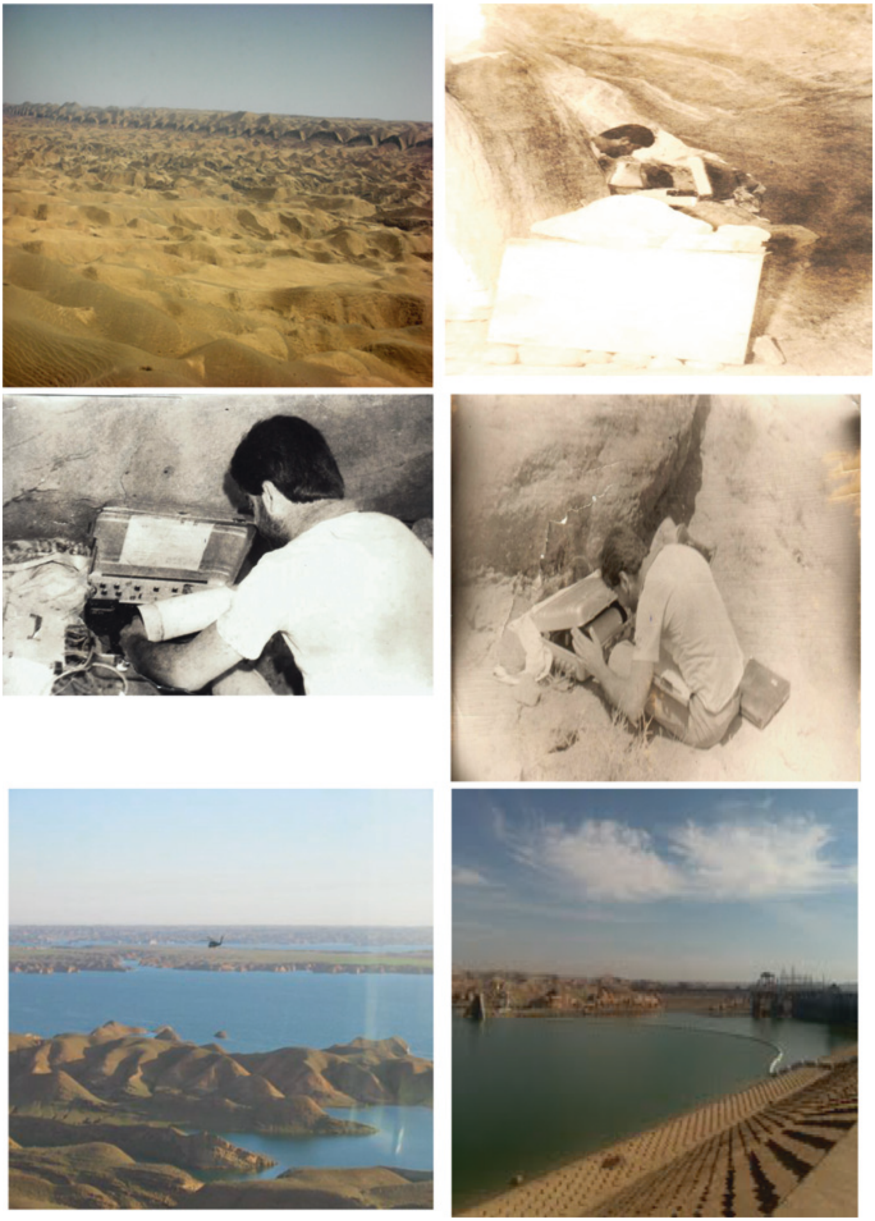

Fig. 2.2 M.Sc. field work and the research site at hemren dam area during 1983

My thesis is entitled "*Microearthquake Monitoring of Hemren Dam Area, Iraqí*". The project involved continuous recording of seismicity for 4.5 months, analysing those records, modelling and data analysis. Historical seismicity was also examined. I concluded that the background seismicity in the area was related to tectonic forces and geological formations. Furthermore, the recorded induced seismicity was associated with the level and residence time of water in the reservoir. Consequently, recommendations were made for operating the reservoir safely and contributed to establishing the seismic code of the area. I completed and passed all the taught modules with an overall First Class mark during 1983.

This research was published a paper in the *Second Iraqi Hydrological Conference,* on the Seismological Engineering considerations for the Hemrin Dam Area (Alsinawi and Baban 1984); I also collaborated with Professor Sahil Alsinawi (my M.Sc. supervisor) and compiled a comprehensive inventory for Historical Seismicity of the Arab Region. This work was published in the *proceedings of the Symposium on Historical Seismograms and Earthquakes of the World* (Alsinawi et al. 1985). The analysis part of my M.Sc. thesis, which dealt with the seismicity of the Hemrin Area, was published in the proceedings of *the 27th International Geological Congress* (Alsinawi and Baban 1986), and was revised and published as my first publication in a referred journal paper in the *Journal of Geological Society of Iraq* (Alsinawi and Baban 1986). My M.Sc. thesis also produced 4 conference abstracts for conferences in the *Union of Soviet Socialist Republics* (USSR) and Japan (Baban and Alsinawi 1984a, b, 1985).

During October 1985, I was offered and accepted the post of a *Geophysicist and Party Manager Assistant* by the Exploration Division in the Iraqi National Oil Company. Here my duties included supervising all scientific aspects from planning to production and quality control as well as performing all Geophysical duties in the seismological party. I was also responsible for managing and motivating a team of 150 staff working under severe conditions.

All through this period, I developed an interest in communicating science to the public through writing for popular science magazines with wide circulations in the Middle East, these included articles in *Uloom (Science) Journal* with topics ranging from the *Causes for the formation, development and distributions of deserts on the planet earth* (Baban 1985a) to *Large sea creatures committing suicide or being misguided by the magnetic field* (Alsinawi and Baban 1986) as well as *Space imagery unveils similarities between Earths and Mars deserts*. I also developed articles for several National Newspapers in Iraq including articles on *Glaciers and the awaited ice age* (Baban 1985a), and articles on the possibility of predicting earth quakes including an article entitled, *Can animal's strange behaviour prior to an earthquake be used as a prediction tool*? (Baban 1985b). These activities paid reasonably well and formed an unexpected and welcomed source of income.

2.3 Geo-hazards Science and Management in the UK

My geo-sciences background and knowledge was helpful for obtaining two posts immediately after completing my Ph.D. from the School of Environmental Sciences, University of East Anglia. First, I was employed as a *Research Associate* dealing with coastal zone management scenarios (Fig. 2.3). Here, I was

Fig. 2.3 Coastal erosion in east Anglia UK

responsible for categorising and mapping urban patterns in the coastal areas of East Anglia and estimated natural and defended rates of erosion and contributed to calculations of resulting economic losses. In addition, I examined possible scenarios (Abandon to nature, Stand firm and nourish and Set back and rebuild) for each coastal sector and recommended the most cost effective scenario within a certain time span. My second post was a *Senior Research Associate* analysing the solid geology and relief information for selected parts of the UK. Here, I analysed, modified and established new solid geology sub-groups within the defined groups. Furthermore, I formulated the datasets and established a database for the solid geology and relief information.

At Coventry University, my interests in Geo-sciences were strengthened through postgraduate research, funded research and consultancy activities. Through a successful Ph.D. student (in association with Dearing), I was involved with measuring and mapping magnetic susceptibility of topsoil's in England; and using soil magnetism to identify and map environmental pollution. This research produced a publication in *Geophysics Journal International* (Dearing et al. 1996) and a publication in the journal of *Physics and Chemistry of the Earth* (Hay et al. 1997) and a conference presentation (Fig. 2.4). Through another successful Ph.D.

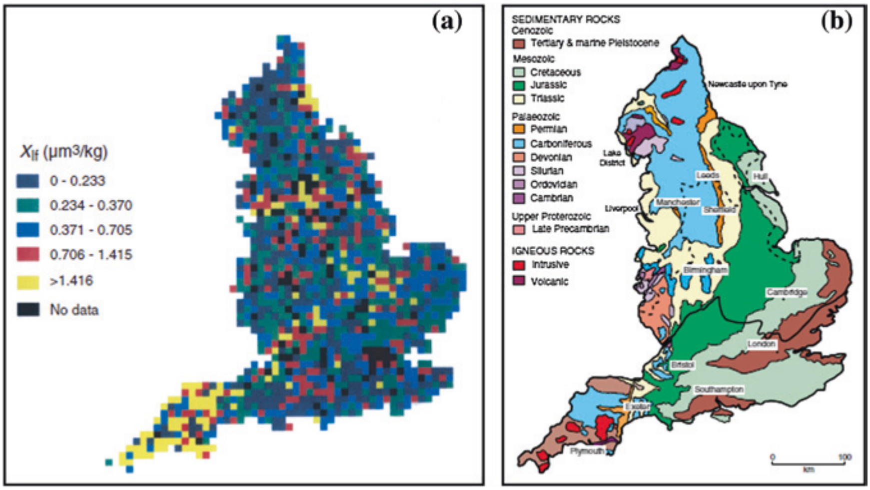

Fig. 2.4 Magnetic suitability values for english topsoils (**a**) and major cities, geological and glacial limits in England (**b**) (Dearing et. al. 1996)

student (in association with Ian Foster), we examined the spatial variability of soil nitrates in arable and pasture landscapes, nitrate leaching and the development of Geographical Information System to model this process. The thesis aimed to support the implementation of Nitrate action programmes. Some of the outcomes dealing with the development processes for setting up a GIS for mapping nitrate vulnerability was published in the proceedings of the *National Hydrological Society/Midlands Research Meeting* (Wade et al. 1993) whilst issues dealing with the spatial variability of soil nitrates in arable and pasture landscapes and the implications for the development of Geographical Information System models of nitrate leaching was published in the Soil *Use and Management* journal (Wade et al. 1996).

2.4 Geo-hazards Science and Management in Malaysia

During 1996, in a conference, I met some colleagues from Malaysia, it was then I was made aware that soil erosion is a critical problem due to large scale land clearance operations driven by rapid development on Langkawi Island (Fig. 2.5). Hence, I suggested that Land degradation has always been associated with the failure to identify areas that are prone to soil erosion. I proposed and they agreed that having a soil erosion map would be useful in the decision-making context to avoid land acquisition in the erosion risk areas or alternatively to recommend soil conservation measures to reduce soil loss if developments were to continue. A few months later, I started to supervise a Malaysia Ph.D. student working on these issues in Lagkawi Island, Malaysia. Whilst conducting fieldwork on Langkawi Island during

Fig. 2.5 Land clearance and deforestation in Malaysia due to the development process as well as growth of oil palm estates

1997, meeting local scientists and recalling previous discussions, I am become involved. An additional factor for increasing deforestation and land clearance on a large scale is the growth of oil palm estates as most of the world's oil palm trees are grown in Malaysia. A report published in 2007 by the United Nations Environment Programme (UNEP) acknowledges that oil palm plantations are now the leading cause of rainforest destruction in these two countries (Fig. 2.5). I learned that land surveying using conventional methods is expensive and time consuming. In contrast, mapping soil erosion using the integration of remote sensing and GIS could identify areas that are at potential risk of extensive soil erosion and provide information on the estimated value of soil loss at various locations. In addition, it can provide answers to spatial queries; for instance, whether the erosion is associated with specific factors such as the loss of continuous vegetation cover. Our review showed that the Universal Soil Loss Equation (USLE), developed by Wischmeier and Smith (1978), has been used within a Geographical Information System (GIS) framework to calculate the total erosion loss. Furthermore, the spatially distributed parameters involved in the equation such as topography and land use, could

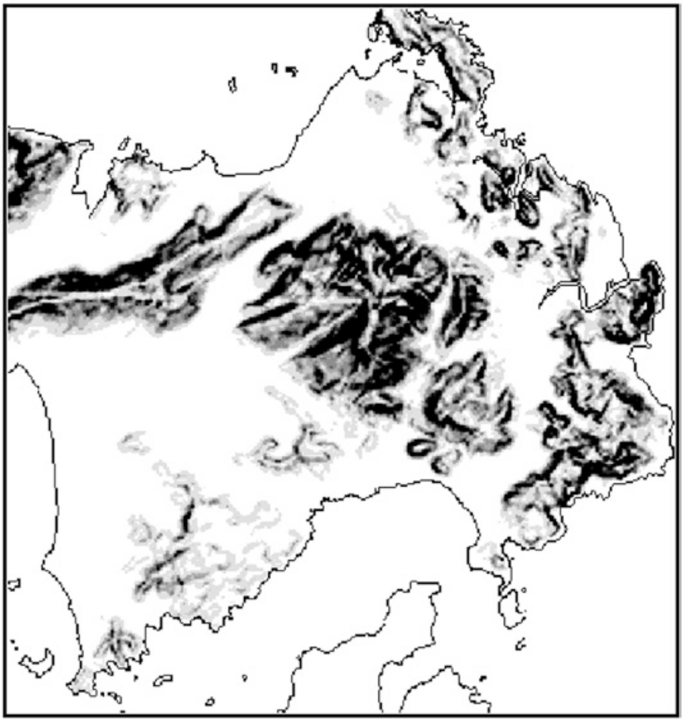

Fig. 2.6 High erosion risk areas (Wan-Yusof and Baban 1999)

be generated by remote sensing techniques (Moore and Wilson 1992). These can then be converted into raster layers to input into a GIS to be analysed and, to produce a soil erosion risk map. I noted that in Malaysia, several soil erosion studies have been conducted using this approach. These include the soil erosion study of the Bakun Dam project (Samad and Abdul Patah 1997) and soil erosion risk assessment for genting highlands (Jusoff and Chew 1998).

My research, through the Ph.D. project, developed a soil erosion risk map for Langkawi Island, using the Universal Soil Loss Equation (USLE), remote sensing and GIS. Spatially modeling soil erosion in the GIS required generating representative raster layers based on secondary data for the following parameters in the equation; rainfall erosivity, slope length/gradient, soil erodibility and conservation practices. Landsat images were utilised to produce a land use/cover map of the Island. This map was then, used to generate the conservation practice factor in the USLE equation. Upon comparison, the produced erosion map showed significant similarities with an erosion risk map of the Island produced by conventional means in 1986. The majority of high erosion risk areas were confined to the highlands (Fig. 2.6). This erosion risk map was a valuable resource for planners to minimise soil erosion problems caused by future and ongoing development projects on the Island. This process can be repeated in the future using updated

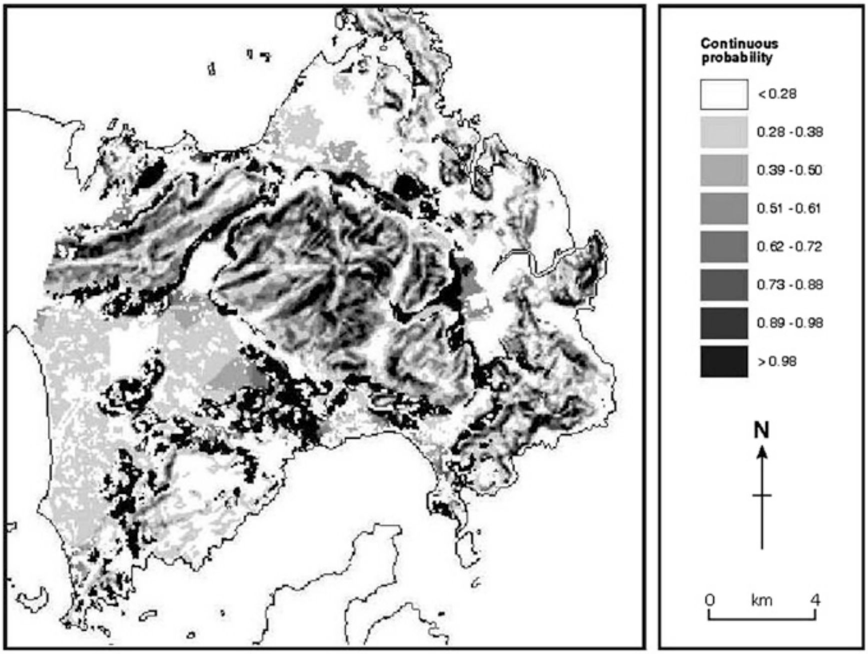

Fig. 2.7 Probability of soil erosion assuming a 10 % risk (Baban and Wan-Yusof 2001)

remotely sensed data to monitor and manage all related issues. This work was presented and published in proceedings of the 20th *Asian Conference in Remote Sensing* (Wan-Yusof and Baban 1999).

Our approach and the GIS in this context was the norm then, however, it occurred to me that this approach is based on two assumptions; firstly, the datasets are free of errors and secondly, the decision rule does not add any error to the final outcome. However, it is evident that all geographically based datasets contain incorrectness. Furthermore, there are uncertainties associated with the decision rule originating from the way in which criteria are coupled to reach a decision. This realization has encouraged me to move towards less rigid decisions, where; given the uncertainties in the data and in the decision rule, it is possible to convert the rigid results of traditional GIS decisions into malleable probabilistic outcomes which present the outcomes in terms of the likelihood of soil erosion in specific geographic locations. This approach has introduced the concept of acceptable and unacceptable risk into the decision makers considerations. Hence, I developed an approach to produce soil erosion probability maps under various case scenarios, by accounting for uncertainties in the data and in the decision rule, using the Universal Soil Loss Equation (USLE), remote sensing and GIS. The outcomes were two continuous probability soil erosion maps indicated that accounting for the uncertainties has in general decreased the probable soil erosion risk. Assuming a 10 % risk (Fig. 2.7), this impact has increased by 12, 11.8 and 5.7 % for high, medium and low soil erosion risk areas on the Island respectively. This research has added a valuable tool for decision makers based on the binary approach to risk management, i.e. acceptable and not acceptable risk, it was recognized by the scientific community and published in the *Hydrology Sciences Journal* (Baban and Wan-Yusof 2001).

2.5 Geo-hazards Science and Management in the Caribbean

When I arrived in Trinidad and Tobago, which is a partially hilly and mountains tropical environment, during September 2000, I noted a large number of landslides on the hillsides, was told about the flooding problem in the region and how these events tend to dominate all aspects of life when they occur. Having lived in England I thought we *have landsides* and *floods too, but life goes on…* I had a very real awakening during November (and every November for the next 7 years), the rainfall was copious and relentless, the landslides started to block some of the main road networks and the floods were ravaging residential areas and farms. This was different from anything I had previously experienced, it had a direct impact on daily life and was touching everyone on the Island, my neighborhood was flooded, outside my office on the Campus was flooded then pubic service was disrupted, the price of vegetables doubled over night and so on. It was very personal. Evidently, due to land space and economic limitations, the effects of landslides and floods had a significant impact upon the livelihood and the economies of small mountainous tropical islands such as Trinidad and Tobago. This is mainly due to the existing favorable physical conditions, as it became clear after several field visits, for landslides and their triggers, lack of effective management coupled with the increasing demands of development, tourism and population growth.

I was called upon by the community and the University, to help develop some solutions and options to manage Geo-hazards on the Island and naturally, I was keen. However, it became clear that the absence of a recording system for landslides and floods was hindering the investigation of landslide susceptibility in many Caribbean Island States. This in turn has had a negative influence in the formation of proper National Planning Policies and Property Insurance Systems. In the worst cases scenarios, developments are permitted on slopes liable to failure without adequate slope stabilization.

2.5.1 Landslides

During this period, I learned that landslides in the Caribbean can occur as a result of a number of determining and triggering factors (Fig. 2.8). Therefore, landslide susceptibility analysis will invariably require the identification and

Fig. 2.8 Landslides in Trinidad and Tobago, West Indies

quantification of these factors (Varnes 1984; DeGraff et al. 1989). In practice, any single or combination of technique(s) may be employed for landslide hazard analysis and there is generally no accepted single method that can be applied to all situations and environments. The selection of an appropriate landslide hazard modeling approach is therefore dependent upon the management scale, site-specific conditions and data availability (Carrara et al. 1997). In this context, the Geographical Information Systems (GIS) is a promising instrument in the analysis of landslides and floods through its ability to handle large data sets, providing an efficient medium for analysis and display of results, with a powerful series of tools that allow the collection, retrieval, manipulation and display of spatially referenced data representing the real world. Furthermore, GIS allows the integration of quantitative and qualitative data through their spatial distribution to yield spatial relationships that may not be evident otherwise. My research, within a year, developed a focus founded on the need for developing prediction approaches and progressed based on advancing a deductive approach for studying landslides founded on the concept that *conditions at known landslide sites within an area are reliable indicators of where future slope failures might occur.* More specifically; Landslides in the future will most likely occur under geomorphic, geologic, and topographic conditions that have produced past and present landslides. Underlying conditions and processes which cause landslides are understood; and relative importance of conditions and processes contributing to landslide occurrence can be determined and each assigned some measure reflecting its contribution.

My research developed and implemented GIS assisted methods for landslide susceptibility analysis for tropical mountainous environments using a varied weighted method. This was based on the concept that hazard assessments are estimations of an area's susceptibility to landslides based on key factors, such as topography, geology and land use/cover. Furthermore, that each factor is capable of being mapped and the number of conditions present in an area can then be factored together to represent the degree of potential hazard present. This research was published in *the Asian Journal of Geoinformatics (*Fig. 2.9) (Baban and Sant 2004). The concept was also tested and implemented for the Island of Tobago using geo-environmental indicators and was published as a chapter is a book dealing with managing Geo-hazards in the region (Baban and Sant 2008). Furthermore GIS and multi-criteria evaluation techniques were used to map landslide susceptibility in Tobago and the outcomes were published in the *Caribbean Journal of Earth Sciences* (Fig. 2.10).

I was also involved with developing a GIS based approach for locating and mapping critical slopes in mountainous tropical environments, examining Tobago as a case study, using factors (geology, slope, aspect, soil, rainfall and land use) that positively influence landslide occurrence. The outcomes were published in the West *Indian Journal of Engineering* (Baban and Sant 2006). Finally, I developed a number of geomorphological indicators for recognizing unstable slopes in Trinidad and Tobago and proposed preliminary management options. This work was published as chapter in a book dealing with geo-hazards management in the Caribbean region (Fig. 2.11) (Baban and Ritter 2008) and the possible applications to hillside developments was published in the *Journal of Sustainable Development* (Baban et al. 2008).

My research team also developed and published some general concepts for mapping landslides using geo-environmental indicators and to proactively managing geo-hazards (Baban 2009a, 2011). Finally, as non landslide specialists often tend to identify areas prone to landslides and endangering the public, our team

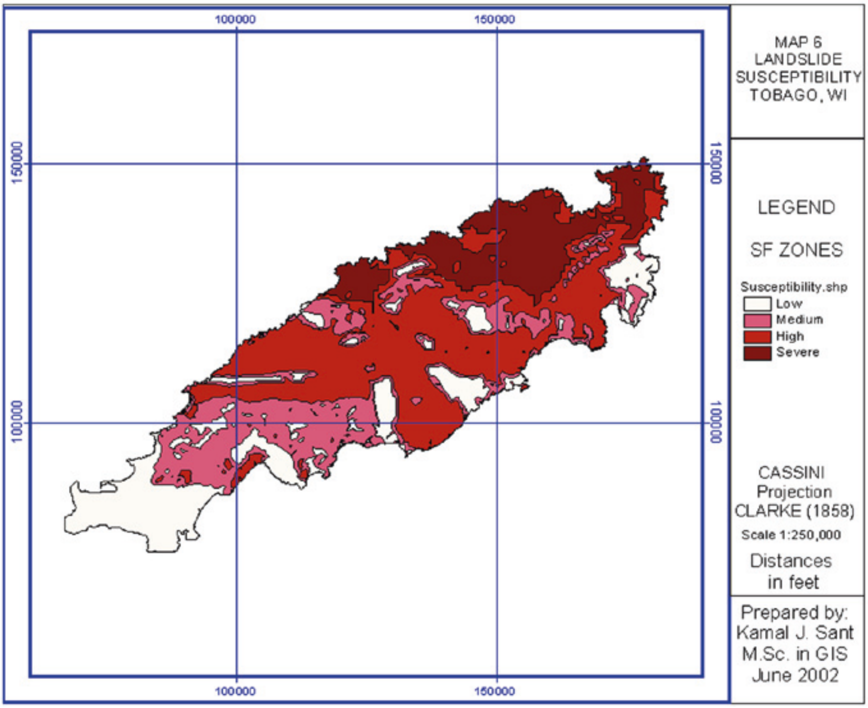

Fig. 2.9 Tobago landslide susceptibility map (Baban and Sant 2004)

developed a rapid field based assessment for non specialists (Baban 2009b), this has proven to be a simple practical tool for identifying potential areas prone to landslides and it is currently being used this purpose.

2.5.2 Floods

In Trinidad and Tobago flooding is a major problem occurring frequently and causing injury to persons, damage to infrastructure, economic losses and general destruction (Fig. 2.12). Flooding is seen as an increasing problem due to the combined and interlinked associations amongst population growth, development, economy and deforestation. As population increases, the need for cleared land to locate basic amenities such as electricity, pipe-borne water and roads increases. As a consequence, squatting for both housing and farming have increased, especially on hillsides, which means removing the trees and other vegetation. In fact, the Land Settlement Agency of Trinidad and Tobago now estimates the number of squatter households to be about 25,000 (Forestry Report 2001).

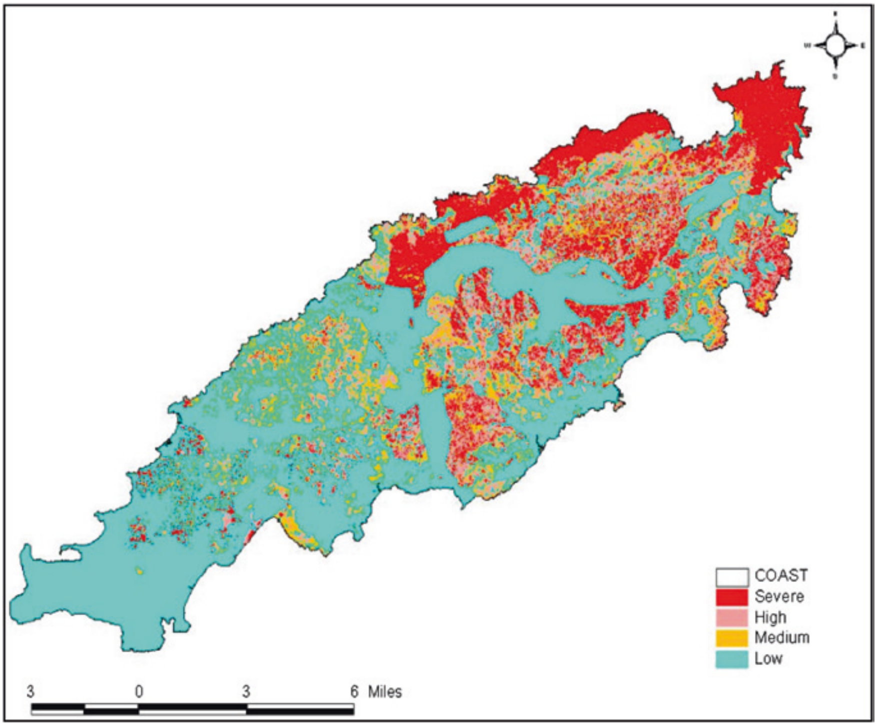

Fig. 2.10 Developed landslide susceptibility distribution map for Tobago (Baban and Sant 2005)

According to Menne et al. (2000), the main causes of flooding include:

- Climatic Effects: these involve the combined effects of weather systems (Cold and Warm fronts) wind speed, humidity and pressure.
- Topographic Effects: the presence of highlands can cause convectional rainfall.
- Anthropogenic: slash and burn, no soil conservation measures, blocked water-courses due to dumped and discarded litter, etc.

The orderly development of land, in feasible areas, is of utmost importance in managing all natural resources. The dramatic increase in population has led to an increased demand for land for housing, agricultural use and industrial sites. In the real world situation survival of the fittest leads to the grabbing of "prime land" by the financially able in society leaving others to fend for themselves. Those who cannot afford housing develop haphazard, illegal squatting settlements and farmers whose income does not allow them to purchase rich lands on the plains, turn to the mountain slopes for their survival. These approaches lack any real short or long term planning and their chaotic nature can lead to deforestation and soil loss, which in turn can cause flooding.

The Environmental Management Authority (EMA) of Trinidad and Tobago in their Environmental Impact Assessment Report (1992) sited the destruction

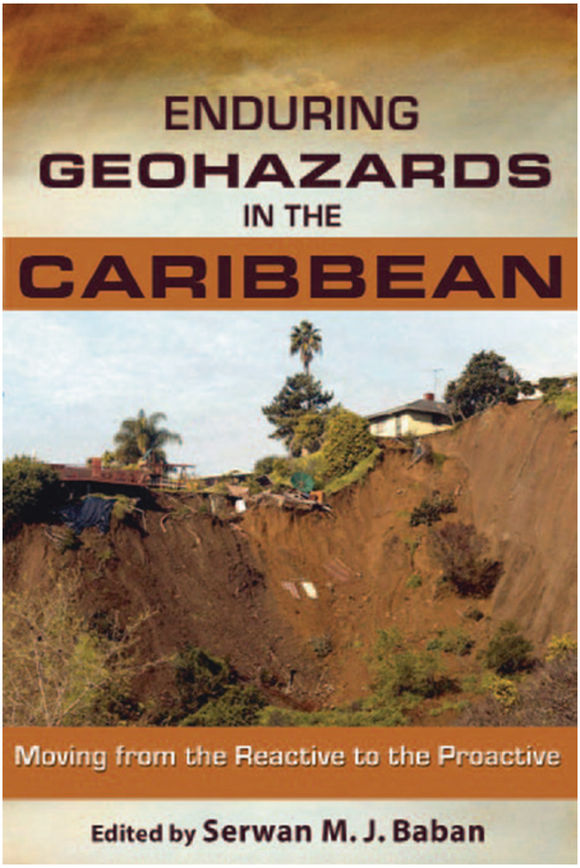

Fig. 2.11 Enduring geo-hazards in the Caribbean book

of watersheds as a major environmental problem. The destruction of watersheds result in loss of habitat for a wide variety of plants and animals and secondary effects include landslides and flooding, which causes damage to infrastructure, loss of property and possible loss of life. I have developed a view that to effectively deal with this problem, there must be an understanding of the intricate relationships existing between the eco-system and socio-economic activities in river basins.

GIS analysis is developed to examine spatial and temporal patterns and to find associations between various geographical factors. Since flooding is a spatial phenomenon and is a consequence of a number of factors (including soil type, vegetation cover and type, rainfall intensity, rainfall frequency, etc.) the GIS will allow the user to handle, manage and analyse the spatial data sets to determine which factors have which effect and to foresee the resulting consequences. One of the strongest assets of a GIS is the ability to carryout temporal analysis, which is essential for flood prediction. By storing data on previous floods, soil types and river channel size. It is possible to create a model of peak flow, discharge and

Fig. 2.12 Floods in Trinidad and Tobago, West Indies

runoff to determine what the consequences would be for a rainfall incident of a particular intensity and frequency. In terms of the impacts of land use/cover on flooding, GIS can not only be used to map change but also be used to identify trends, both visually and statistically, between land use changes and flooded areas. The use of a GIS allows further spatial analysis of the data derived from remotely sensed images and analysis of the impact of land cover change on regional sustainable development. The development of a flood risk assessment map is essential for planners and decisions makers in timing steps during pre-disaster preparation and post-disaster activities for the assessment of damages and losses due to flooding. Additionally, for developing countries where there is insufficient long-term datasets GIS can still be implemented with some level of success. Flooding cannot be completely avoided, but damages from severe flooding can be reduced if an effective flood prevention scheme is implemented.

My first research project dealt with the St. Joseph flood during November 2001 as indicated before. I found out that within the St. Joseph watershed, development in the agricultural sector and an increased need for housing for a growing population has lead to removal of the natural vegetation which has been replaced with pitched roads, concreted yards, galvanized roofs and bare soils. Not only has the earths' natural barrier been stripped, but the development in both sectors has been haphazard so that controlled rainfall runoff is difficult, if not impossible. Using field based data and GIS; I examined, through an M.Sc. project, the factors that may have played a part in flooding in the St. Joseph Watershed on the 5th November, 2001; including rainfall, deforestation, development/housing and squatting. As a result a Flood Risk Assessment Map (FRAM) for the St. Joseph Watershed was developed. Data collection and development included traversing,

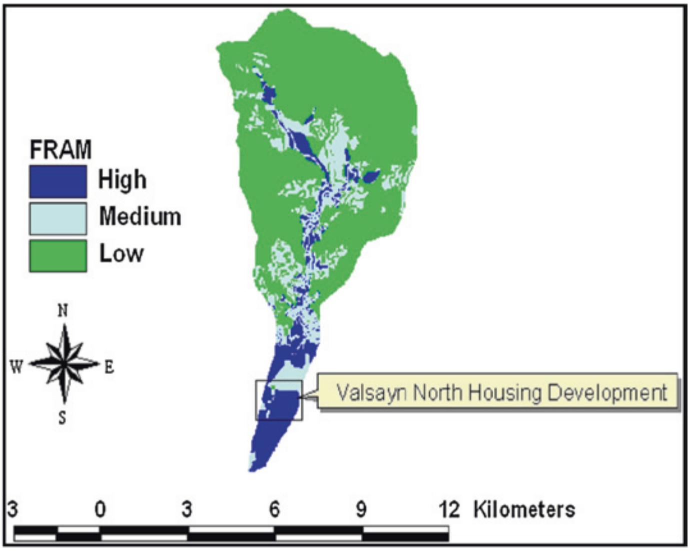

Fig. 2.13 The flood risk assessment map (FRAM)

collecting cross-sectional data for the river, developing information layers for road, soil, and vegetation. Additionally a Flood Depth and Extent Map for the Valsayn North Housing Development was developed and linked to population and losses due to the flood event of November 5th utilizing questionnaire, field survey data and photos (Fig. 2.13). A comparison between the latter and the developed FRAM indicated that the FRAM although basic has managed to predict areas susceptible to flood risk correctly. This study showed the power of GIS as a tool for developing both a FRAM, as well as flood depth and extent maps within a localized area (Valsayn Housing Development) and at a watershed scale, however it is important to note that the use of rainfall and climatic data and the analysis of these are essential in the overall development of any GIS output map. The development of a Flood Risk Assessment Map is indeed essential to allow the identification of possible risk factors and their location as well as the impact of each risk factor. Additionally the FRAM will give authorities greater foresight to areas that may be at risk so that preventative measures (physical earthworks or enforcing legislature) can be undertaken. These measures will not only aid in flood reduction but also, and probably more importantly the reduction in loss of infrastructure and life. This paper was published was presented in an international conference and published as a chapter in *IAHS Publication* (Baban et al. 2006). This concept was expanded to include flood sensitivity mapping and was published as chapter in a book dealing with geo-hazards management in the Caribbean region (Baban and Kantasingh 2008).

My second project dealt with Flooding in the Caparo River Basin which is considered to be a major problem in Trinidad. In the last few years especially; there have been many severe flooding events which have led to significant damage to livestock, agricultural produce, homes and businesses. I formed a view that there is therefore an urgent need to introduce mitigation measures to ensure that these areas are protected so that erosion and flooding is minimized. The first step in achieving this is to identify the nature and extent of vulnerability of the areas under consideration. Next, determine the most appropriate mitigation measures that should be used to address the problem. Finally, these measures must be implemented and maintained. Clearly there is a need for developing flood mitigation and management strategies to manage flooding in the areas most affected. This research utilised GIS to map the extent of the flooding, estimate soil loss due to erosion and estimate sediment loading in the rivers in the Caparo River Basin. In addition, the project required the development of a watershed management plan and a flood control plan. The results indicated that flooding was caused by several factors including clear cutting of vegetative cover, especially in areas of steep slopes that lead to sediment filled rivers, narrow waterways, poor agricultural practice, and uncontrolled development in floodplains. Hence, problems stem from the inappropriate use of lands that are vulnerable to erosion, quick water runoff and slope failure. Poor land use practices include slash and burn agriculture, quarrying, illegal logging, forest fires, and illegal settlements. These have lead to the soil becoming more exposed and therefore more susceptible to being washed away during periods of heavy rainfall and subsequent runoff. Consequently, heavy sedimentation occurs in the river channels causing these channels to be reduced in size. This ultimately leads to flooding (Fig. 2.14). In addition, the lack of vegetative cover leads to much shorter lag times between rainfall and the water reaching the waterways causing the already reduced channels to overflow leading to massive floods. Inappropriate land use is further exacerbated by several problems including the absence of relevant information on the level of vulnerability of different areas to damage due to these usages, the lack of political will to address the problems and the lack of adequate resources for the relevant authorities to enforce the laws of the country. For this study, GIS was successfully used in determining the extent of the problem including the identification of areas that needed conservation, the extent of soil loss and flooding at different sections of the watershed. The analysis provided by GIS made it possible to expedite the development of mitigation strategies that are most likely to address the anticipated changes in the river basin. Flooding in the Caparo River Basin may be mitigated if the recommendations provided are implemented in its entirety since the proposed strategies comprise of many interdependent components. Piecemeal implementation will not provide the appropriate results. This research was published in the leading journal in the filed, the *Journal of Environmental Management* (Ramlal and Baban 2008).

My third project dealt with developing and implementing a ‘flood prone areas’ concept. I was motivated by the facts that flood-prone—area maps can be used for flood hazard identification, regulation of future development, helping communities to understand where flood-prone areas are located, establishing flood insurance premium rates, and identifying areas having unique, natural and beneficial functions. Clearly, the actual impact of flood events depends mainly on the physical characteristics and the conditions of hydrological catchments. For example, if the

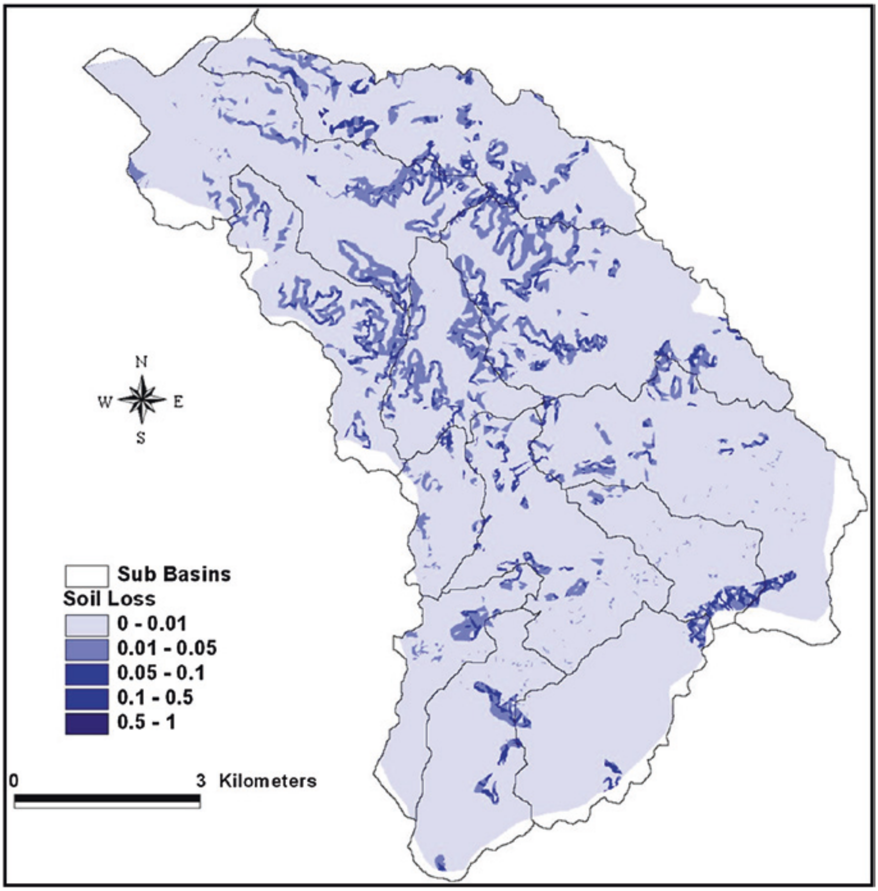

Fig. 2.14 Soil loss estimation for the Caparo river basin sub-catchments (cubic meters/sqkm). It should be noted that the blank areas on the boundaries of the map represent data gaps (Ramlal and Baban 2008)

topography of the catchment is steep, the velocity of the floodwater will be great, thus causing destructive damages, though the inundation areas would be limited and the duration short. However, if the topography of the catchment is gentle, the flood will be extensive and will last for a long period. Furthermore, if the vegetation cover and distribution within a catchment is poor, and the geology is fragile, the flood will carry and contain large amounts of debris and will be more destructive. Since humans historically have established settlements in river valleys, floods have created hazards for human communities for centuries. In turn, human activities involving environmental degradation, deforestation and inappropriate land use, often encourage flooding. Riverine flood waters often carry a considerable amount of sand, silt and debris that can block channels and dams, intensifying flooding upstream. It is evident that most of the extensive flood-prone areas are located along the coastal plains and riverine areas, which tend to coincide with densely populated and highly built-up areas.

Literature (Cooke and Doornkamp 1974; Smith 1991) indicates that the following are the most vulnerable landscape settings for floods:

1. Flat and low lying or areas with gentle slopes with poor drainage, in their natural state. These settings will suffer the most frequent flooding.
2. Low-lying coasts, deltas and estuarine areas are often exposed to a combined threat of floods from rivers and high tides.
3. Small catchment basin, basins characterized by a combination of steep topography, little vegetation and heavily developed urban settings.
4. Areas below unsafe or inadequate dams.
5. Low-lying inland shorelines.
6. Catchments with rivers functioning with reduced carrying capacity and flow constraints due to vegetation, tidal influences or infrastructure such as bridges and culverts.
7. Watersheds with short longitudinal axes. The time of arrival of a flood wave is generally shorter than for equivalent watersheds having longer longitudinal axes.
8. Watersheds characterized by high runoff, if the surrounding land has a high runoff potential, due to development of impervious soils.
9. Alluvial fans, which tend to have a history of flooding and often provide attractive development sites due to their commanding views and good local drainage.

However, mapping of flood-prone areas requires considerable collection of historical data, accurate digital elevation data, discharge data and a number of cross-sections located throughout the watershed. In the context, GIS provides a broad range of tools for determining areas affected by floods for predicting areas likely to be flooded due to high discharge of rivers. GIS can also be used to create interactive map overlays, which can illustrate which area of a community may be in danger of flooding, thus, coordinating mitigation efforts before an event and recovery after the event. Furthermore, the ability of GIS to develop three-dimensional topographical mapping and terrain modeling in the form of digital elevation models (DEM) is particularly useful for flood analysis and estimation (Jones et al. 1998).

This research aimed to identify flood-prone areas in Trinidad using a variety of sources, including available flood maps, topographic maps, aerial photos, DEM, newspaper articles, and historical data. Based on available data, 106 flood events were identified in Trinidad from 1986 to 2006 (Fig. 2.15). These events were analysed, related to geographical locations, and the areas that were repeatedly flooded during this 20-year period, were identified and mapped. The geophysical terrain characteristics such as slope, elevation, geology and rainfall for these susceptible areas for flooding were derived. These terrain characteristics were then used to identify potential flood-prone areas and to generate a map identifying these areas in Trinidad (Fig. 2.16). The developed methodology is simple and easy to implement. The outcome map is useful for hazard identification, the regulation of future development, and for the establishment of flood insurance premium rates.

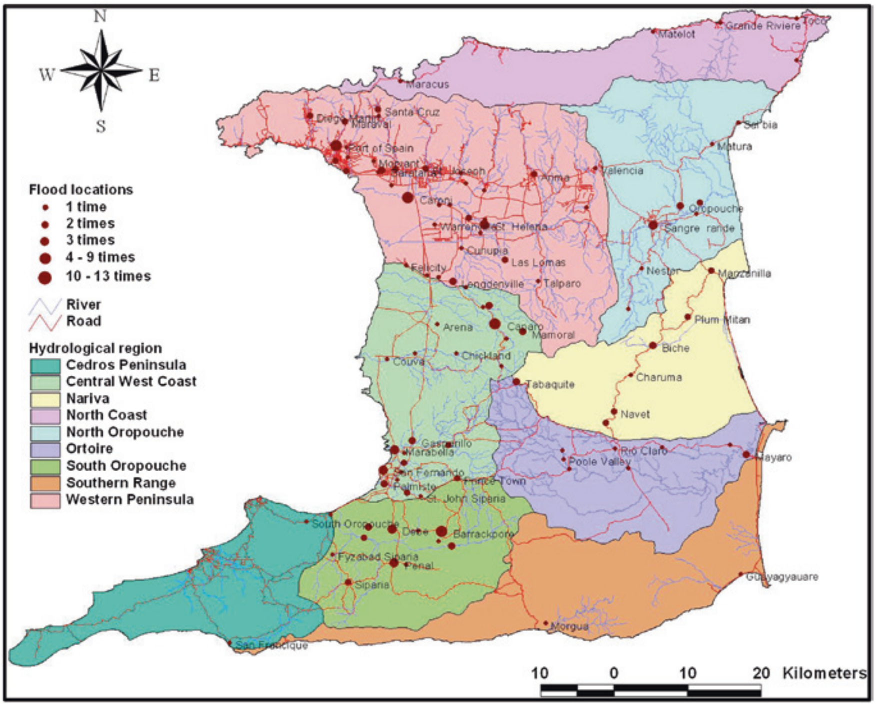

Fig. 2.15 Flood prone areas based on 106 events from 1986–2006 (Baban and Cannisus 2008)

This study shows a simple and cost effective methodology, which uses geographic information systems (GIS) for creating flood-prone maps from the available data on a national scale. It is acknowledged that accuracy of the key information, past records of flooding, and their geophysical characteristics, depends upon the scale that represents them. It is anticipated that the flood-prone map developed in this study will be employed for a range of uses, which may include insurance guidance, flood risk assessments, public awareness of various flood-risk zones, generation of flood-warning schemes, emergency evacuation planning, strategic road network planning, protection of key utility assets, water resources management and land-use planning. Another use of an understanding of the effects of inundation over time will be to help in the construction or reconstruction of infrastructure. If a detailed analysis shows specific flood duration patterns, then structures can be built in a way that mitigates impacts from future storms. The inundation history, conditions and duration, can also be used to make appropriate future planning scenarios. Due to lack of cloud-free satellite images and detailed DEM, we could not access the large-scale flood event and duration maps for critical flood events. Detailed study requires a large amount of local topographical and/or detailed data such as LIDAR and weather independent SAR data. This option is likely to be resource intensive to produce national-level maps. However, in some locations, it may be justified. Other than that, further research is required into

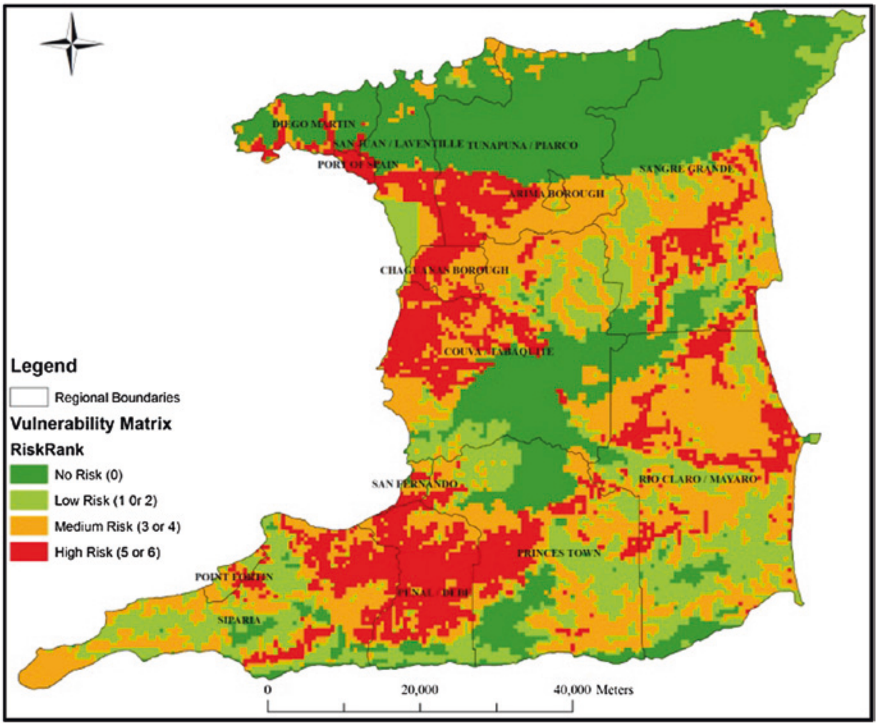

Fig. 2.16 Flood risk map of Trinidad (Baban and Cannisus 2008)

mapping pluvial flooding at the scales necessary for flood risk mapping purposes. This research was published as a chapter in a book dealing with geo-hazards management in the Caribbean region (Baban 1999).

The fourth project examined in more depth, the approach of identifying flood prone areas and focused on linking this idea to development utilising the concept of ‘carrying capacity’ at the watershed level. Clearly, there are advantages of using the watershed as a unit, in mountainous areas as this is not only a unit in the water regime, but is useful as an indicator for allocation of space for agriculture or human settlements. Even though Carrying Capacity has been used as early as 1838 in the context of logistic population growth (which evolved in the Verhulst–Pearl Logistic Equation), the concept of carrying capacity was first developed by Errington in 1934 (Monte-Luna et al. 2004). Although this concept is vastly used, it is still vague and difficult to define, while some believe that the carrying capacity concept should be avoided all together. Applying this to natural disaster management, development in watersheds is inevitable and without proper management and monitoring practices of the resulting physical changes taking place, these developments may result in the watershed reaching its tipping point and lead to Geo-hazards such as floods.

The aim of this research was to identify the carrying capacity of watersheds in Trinidad which indicates the amount of changes a watershed can tolerate before its susceptibility to natural hazards increases. In doing this the following are the objectives:

- Identify the Watersheds affected by Floods, develop a Flood Prone Map and extract watersheds affected and not affected by floods.
- Identify possible contributing factors. Reclassify the Soil, Land use and Geology maps in terms of their contribution to runoff or infiltration rate.
- Examine and quantify the differences between the geology, soil, slope, area, Land use/cover and elevation of the watersheds affected and those not affected.
- Develop the limits which can be tolerated and used as the carrying capacity for the watershed.

For the purpose of this research, carrying capacity has been defined in the context of watershed management and attempts to highlight the tolerable levels of development and changes that can take place within these watersheds before predefined thresholds for the triggers of the geo-hazard, flood, are reduced. As focus is on the tolerable levels of changes before thresholds are lowered, the only interrelated dimension considered is the intensity/duration threshold for floods. This was predefined and applies as a constant to each watershed. It was found that the watersheds of larger area and less steep slopes were more prone to floods. Further examinations revealed that Slope, Elevation and Land use/cover were sufficient to be indicators for Carrying Capacity (Fig. 2.17). This approach is simple and easy to implement. The outcome map is useful for hazard identification, regulating future development, helping communities to understand where flood prone areas are located, establishing flood insurance premium rates, and identifying areas having unique, natural and beneficial functions. This research was published as a conference proceeding in the *Second International Conference on Geoinformatics Technology for Natural Disaster Management and Rehabilitation* (Baban and Aliasgar 2008). Later, it was published in a more comprehensive form in the *International Journal of Geoinformatics* (Baban and Aliasgar 2009). I was also involved in developing early warning systems for managing floods and landslides in the Caribbean based on rainfall intensity, aspects of this work was published as a chapter in book dealing with geo-hazards management in the Caribbean (Baban and Aliasgar 2008).

Another project, I was involved with dealt with developing a Proactive Approach to Geo-hazards Management in Trinidad and Tobago. Over a the period of some 7 years of living and working in the Caribbean, it became clear to me that the current management of floods and landslides is reactive since the major effort is focused on cleaning up operations, post event. Mitigation works are designed to repair infrastructure after the event has occurred. Clearly, there is an urgent need for objective decision-making, and for moving geo-hazards management from being reactive to proactive. However, the lack of an effective and reliable information base makes this transformation difficult. For example, at present there is an absence of a national data depository for hazard events, in which event

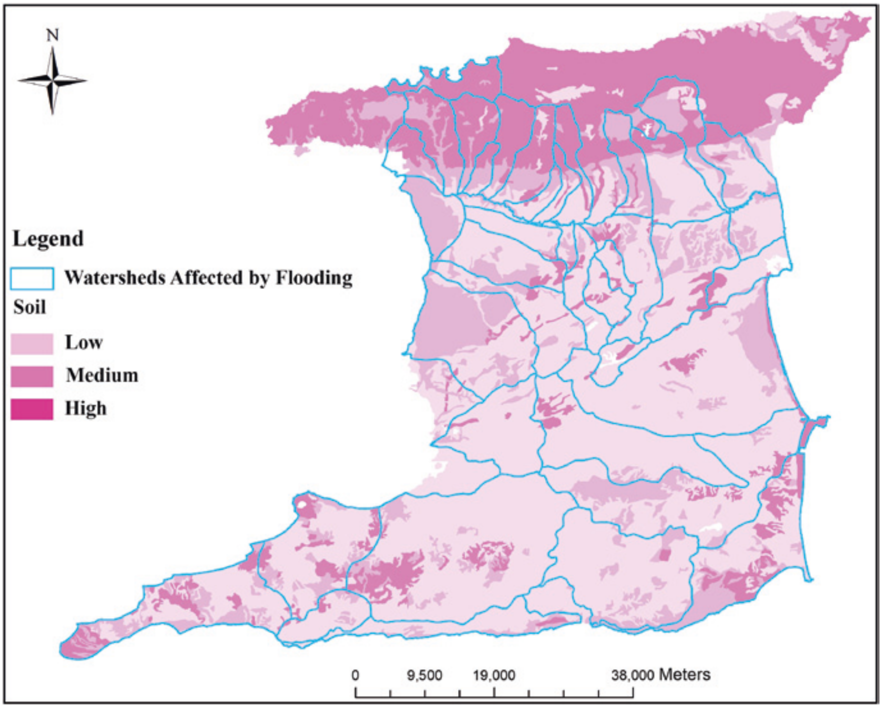

Fig. 2.17 Carrying capacity floods showing the impact of soils (Baban and Aliasgar 2008)

occurrences can be recorded and quantified for post analysis. Furthermore, several governmental agencies seem to be responsible for geo-hazard management. These agencies are neither capable of handling geo-hazards on their own nor do they have effective coordination among themselves. The states in the Caribbean have a number of common characteristics, which make them vulnerable to geo-hazards. These include geography, climate/weather conditions; limited physical size; finite natural resources; dependence on agriculture and tourism; and high population densities concentrated in vulnerable areas, including hillsides and flood plains. In addition, the region is experiencing rapid economic development combined with a fast rate of urbanization, population growth and questionable agricultural practices. Typically, these factors lead to floods, landslides, deforestation, soil erosion and extinction of an unknown number of animal and plant species. Clearly, there is a need to determine strategies to cope with the uncertainties of the effects of geo-hazards on natural resources, the environment, and goods and services. This process will require an understanding of the links between geo-hazards and societal well-being, and the promotion of effective interventions.

Reliable information is one of the most important strategic factors influencing decision-making and development. Nevertheless, there are clear indications that the information poverty obstacle can be overcome by using reputable technologies that facilitate management decisions, such as Geoinformatics, which encompass remote sensing, GIS and global positioning systems (GPS). Geoinformatics contains the necessary tools to collect, handle and analyse the necessary data sets, as well as to expand our knowledge of the processes involved at the appropriate scales. Geoinformatics can provide a means for the unconstrained analysis of conditions that influence landslides and floods. Furthermore, spatial and temporal distribution patterns not apparent within written reports can be highlighted through appropriate maps and early warning systems can be developed, which would help to provide effective information for geo-hazards management. However, it should be indicated that the insufficient funds allocated to obtain information in developing countries is a serious obstacle. In fact one of the barriers to sustainable development in developing countries is lack of information requisite to planning it (Bernhardsen 1992). Evidently, geo-hazards can raise awareness of risk and the need for management. Sadly, in recent times, Trinidad and Tobago has suffered a series of high-intensity rainfall events, these resulted in severe flooding. An understanding of the links between geo-hazards and societal well-being, and the promotion of effective interventions is urgently required. Reliable information is one of the most important strategic factors influencing decision-making and development. However, the Caribbean region, like other developing regions, suffers from a scarcity of reliable and compatible data sets.

The aim of this research was to indicate that a real option for transforming geo-hazard management in Trinidad and Tobago from a reactive to a proactive mode can be through developing a Geoinformatics based holistic approach for disaster management. In addition, this approach can form the basis for developing a national emergency strategy and short and long term priorities, including the establishment of national geo-hazard inventories and databases; the development of early warning systems; as well as the development of effective programmes for public awareness, education and information, and the enhancement of the implementation capabilities of relevant government agencies. Finally, this strategy will need to be implemented by utilizing reliable cutting edge technology such as geoinformatics to overcome information poverty.This research was published as chapter in a book dealing with Geo-hazards management n the Caribbean Region (Baban 2008a).

My research team also developed and published some general concepts for identifying, mapping and managing floods (Baban 2008b), using Carrying capacity and multi-criteria analysis (Baban and Aliasgar 2009), using satellite based rainfall data for predicting floods (Pathirana and Baban 2008), and proactively managing Geo-hazards (Baban 2009a, 2011). Finally, I had the privilege of editing a book dealing with Geo-hazards issues and advocating a proactive approach to Geo-hazards management in the Caribbean region (Baban 2008c).

2.6 Geo-hazards Science and Management in Australia

In Australia, coastal erosion represents a serious problem (Fig. 2.18); hence, shortly after my arrival I was keen to initiate a research project with Darwin City Council in North Australia. This research examined the coastal erosion

Fig. 2.18 Coastal erosion in Darwin, Australia (Baban et al. 2008)

processes occurring based on field observations and remotely sensed data (aerial photographs and satellite images) for the period 1978–2006 (Fig. 2.19). The coastlines were indentified and digitised, erosion was estimated at 59 locations and the distance from each location and the nearest infrastructure was calculated. Then the estimated erosion rates were categorised into low (0–5 m), medium (5–10 m) and high (10–15 m) erosion rates (Fig. 2.20). Coastal erosion ranged from 1.9–17.3 m over a 28 year period with an average shoreline recession of 30 cm per year, these estimates are corresponding well with historical observations. Field observations showed that cliff erosion in Darwin has been exacerbated by surface, groundwater and storm water flows sited near or close to the highly erodible cliffs. Whilst the average erosion rate is not extreme, due to the ongoing caving process, parts of the shoreline could recede by by 5–10 m over a period of weeks, particularly during intense storm events. A range of possible coastal protection measures and recommendations for a coastal management plan was recommended. This project produced a consultancy report (Jones et al. 2008), a conference paper published in *Second International Conference on Geoinformatics Technology for Natural Disaster Management and Rehabilitation* (Pathirana and Baban 2008) and another conference paper in the *Asian Conference on Remote Sensing (ACRS)* (Pathirana and Baban 2008).

Fig. 2.19 Fieldwork examining coastal in Darwin, Australia

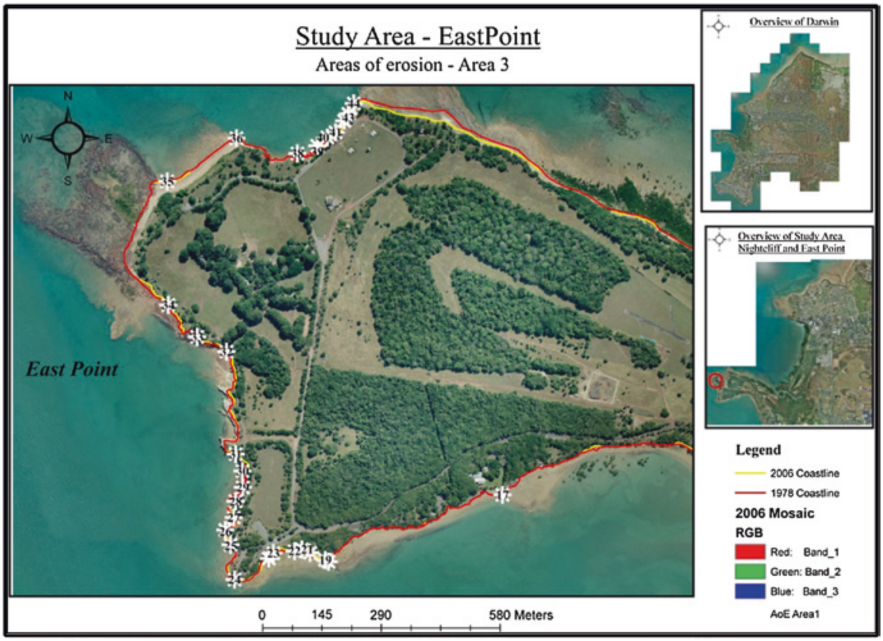

Fig. 2.20 Examining coastal erosion in Darwin, Australia (Jones et al. 2008)

2.7 Geo-hazards Science and Management: A Conclusion

Fundamentally, my research in this field started in Iraq, affording me with an opportunity to understand the research process, to present in national and international conferences and to have my first publication in a refereed journal paper. These early achievements provided me with a standard to aim for, and made me familiar with, the thought processes involved to develop a serious interest in and to focus, understand and attempt to find solutions for geo-based environmental issues. My Geo-sciences background coloured my view of the world and my basic approach to problem solving within my immediate environment and environmental issues that emerged during my employment and relocations from the UK to the Caribbean and Australia.

I learned that the economic, environmental, and social effects of Geo-hazards in developing countries cause loss of life, economic loss and serious degradation to the environment and natural resources. I noted that current management of Geo-hazards in these countries tends to be reactive and focused on cleaning-up operations, repairing infrastructure and providing comfort to affected population post-event. Evidently, there is a need for a proactive approach, planning and informed decision-making. However, the lack of an effective and reliable information base and system makes this transformation difficult. My research developed a focus for advancing a Geoinformatics founded holistic method as the basis for developing a proactive approach for Geo-hazards management in developing countries. I, with the support of my research students and team, have managed to;

1. Develop and implement a reactive and a holistic management approach using Geoinformatics, which contains the necessary tools (Remote sensing, GIS, GPS) to collect, handle and analyse the necessary data sets, as well as through developing early warning systems.
2. Indicate that the focus must be on assisting the most vulnerable groups in society and to develop practical analytical methods: that is, it must be possible for a wide range of Geo-hazards professionals and institutions to use them, and these groups must see an advantage in doing so.
3. Acknowledged that improved data and analysis are not enough by themselves. There should be a vigorous effort to use its results together with other campaigning methods, in order to influence decision makers at every level.
4. I came to realise that the real challenge is in developing practical solutions i.e. science based holistic management options that are;

   i. Simple (easy to understand, coordinate and implement)
   ii. Local/regional in nature (infrastructure, resources and coverage)
   iii. Supported (by decision makers and the local population)

My research team has made significant contributions to several international conferences dealing with the management of Geo-hazard a conference in Fiji (Fig. 2.21) and Thailand (Fig. 2.22). Weg My team achieved several tangible results for Trinidad and Tobago, these included; the development of a national

Fig. 2.21 At the United Nations regional UN-SPIDER workshop, Suva, Fiji, Sept. 2008 and at USP with Dr. Gennady Gienko, head of environmental sciences (last two)

Fig. 2.22 At the second international conference on geo-informatics technology for natural disaster management and rehabilitation, Asian institute of technology (AIT), Bangkok, Thailand, 2008

level emergency strategy; establishing national Geo-hazards inventories and databases; developing an early warning system for floods; using predictive understanding of the processes and triggering mechanisms of Geo-hazards (floods and landslides); setting international level standards for all consultancies and research projects. In addition, to highlighting the need for developing effective programs for public awareness, education and information, as well as enhancing the implementation capabilities of relevant government agencies.

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Chapter 3
Water Resources Science and Management

3.1 Introduction

Related to much of my research interest is an inherent attraction for studying water quality parameters and managing water resources. I have found expression for this pursuit in the application of Geoinformatics to study lakes, rivers, coastal/marine environments, water resources management, modeling water resources and rainfall analysis. This particular interest had its roots firmly set at the University of Baghdad and later at the University of East Anglia, where I completed my Ph.D. My Ph.D. research examined the applicability of remote sensing techniques in various aspects of hydrology, including; modeling and mapping water quality parameters in lakes; bathymetric charting of lakes using remote sensing; mapping water circulation patterns in lakes; examining and analysing the spatial variations in the surface temperature of lakes; trophic classification and ecosystem checking of lakes; environmental monitoring of estuaries using Landsat TM imagery; detecting and mapping the spatial and vertical distribution of fluvial sediment discharge into coastal waters. During my career, this interest has emerged in various guises through involvement in supervising student projects, obtaining research projects and conducting consultancy activities in the UK, Malaysia, the Middle East, the Caribbean region and Australia. Here, I will describe my contributions towards realising that potential.

3.2 Water Resource Science and Management in the UK

Whilst at The University of East Anglia and Coventry University, my research was focused on understanding and managing water resources management and the possible impacts of activities associated with development on land based and coastal aquatic environment. As a result, rivers, lakes, estuaries and coastal waters were investigated.

S. M. J. Baban, *Managing Geo-Based Challenges*, Environmental Science and Engineering, DOI: 10.1007/978-3-319-07380-4_3,

3.2.1 Rivers and Lakes

3.2.1.1 Water Quality Parameters

Despite the fact that a good deal of work has been carried out on the water quality problems in the Norfolk Broads, examining available information indicates clearly that these are unsystematic only involve few Broads at one time. Furthermore, the information has been obtained by different individuals for different purposes, therefore the quality and the quantity of this makes following the ecosystem state of a group or a particular Broad or comparison between different Broads difficult and perhaps inconsistent. However, even in the absence of measurements, there is considerable informal knowledge of differences between various Broads. It is possible to use this general knowledge to check the outcome of work using the overview of a Landsat image. Landsat imagery has obvious advantages over the traditional point sampling methods as the nature and the distribution of some of the variables requires a synoptic coverage, making the shipboard sample collections rather unsatisfactory; for instance the distribution of suspended solids, changes rapidly with fluctuations in tidal and wind conditions and river discharge and also shows considerable spatial variations; and chlorophyll tends to have a "patchy" distribution. Therefore, remote sensing seemed a practical tool for studying an area such as the Norfolk Broads allowing the examination of large numbers of the Broads at the same time or compare individual Broads or groups in terms of their water quality.

My research examined the water quality parameters of chlorophyll a, total phosphorus, Secchi disk depth, suspended solids, salinity and temperature in the Norfolk Broads using various TM bands and band combinations. I have managed to develop statistically significant algorithms between information extracted from remotely sensed data and ground referenced data for these parameters. These algorithms were used to predict and map these parameters in 27 of the Norfolk Broads (Fig. 3.1). In terms of evaluation, all the predicted outcomes were consistent with the available general knowledge about these Broads. This research and findings were considered to be significant at that time and were published in the *International Journal of Remote sensing* (Baban 1993a).

My research also dealt with mapping water circulation in lakes using both reflective (TM1) and the thermal (TM6) remotely sensed data to map water turbidity and surface temperature in Barton (Fig. 3.2) and Wroxham Broads, two of the Norfolk Broads. Based on the outcomes, it was possible to map water circulation patterns in both Broads. The results indicated that the through-flowing path of the River Ant in Barton Broad is the major influence on the distribution of suspended solids/turbidity as well as surface temperature (Fig. 3.3). In Wroxham Broad, both turbidity and surface temperature displayed a uniform distribution. This could be explained by the absence of a predominant direction of flow. This was considered to be significant by practitioners for mapping water circulation and was published in the *Journal of the Institute of Water and Environmental Management* (Baban 1994).

I have expanded the previous idea and become interested in evaluating the influence of water depth, volume and altitude on the variations in the surface

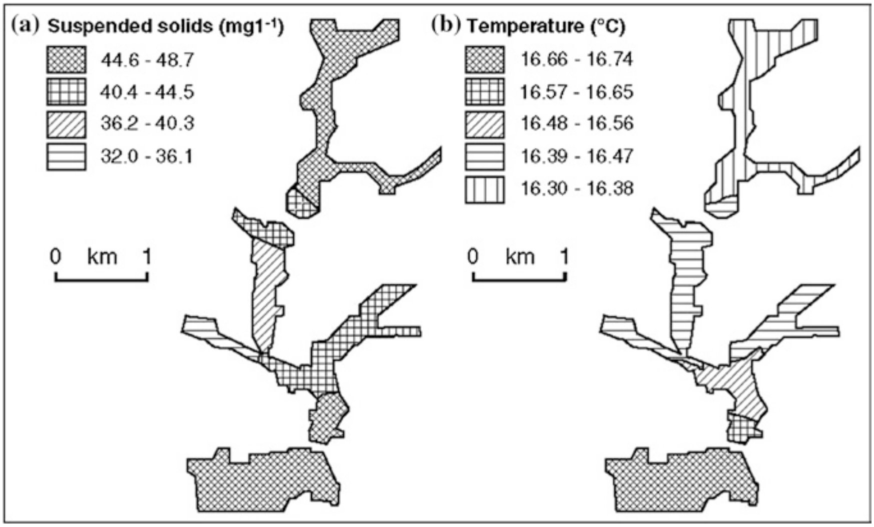

Fig. 3.1 The distribution of calculated **a** suspended solids, **b** temperature in the Trinity broads

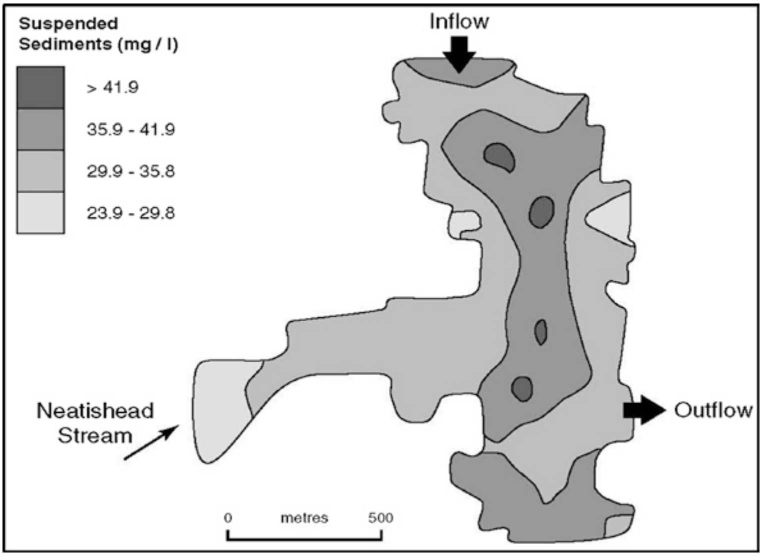

Fig. 3.2 Map of calculated suspended sediments distribution using remotely sensed images in Barton Broad (after Baban 1994)

temperature of lakes and if remotely sensed data can used successfully in this processes. In this research, I examined the usefulness of the Landsat thermal band (TM6) has been used to map the thermal pattern in three lakes of the English Lake District, Cumbria. The patterns were clearly associated with the variations in the

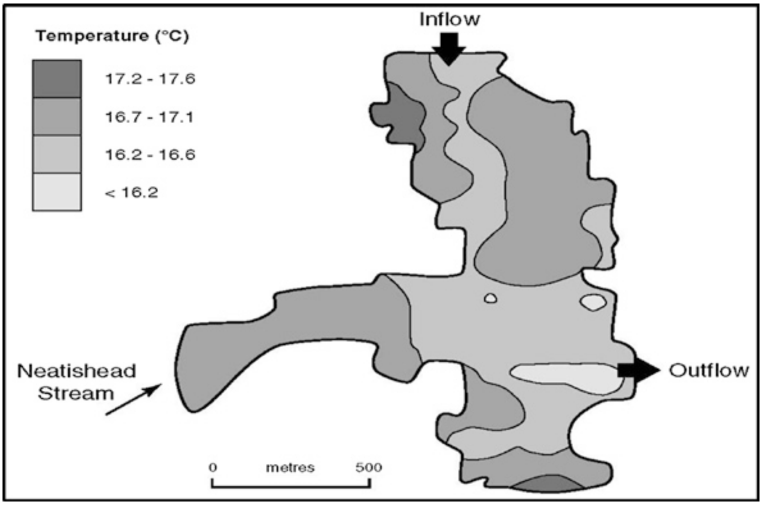

Fig. 3.3 Map of calculated surface temperature distribution which shows the water circulation pattern in Barton Broad (after Baban 1994)

depth (Fig. 3.4). The cause of the formation of this pattern is thought to be solar warming of water. The influence of water volume and altitude and the surface temperature and the relation among them were formalised in an equation involving 16 lakes. This research and findings were considered to be significant at that time and were published in the *International Journal of Remote sensing* (Baban 1993c).

Whilst conducting work on the water circulation research, I noted the influence of water depth and wondered if remotely sensed data can be used for developing bathymetric maps in lakes with clear water. Here, with the aid of ground referenced data, I examined the effectiveness of two well known and utilized algorithms for bathymetric mapping. Namely; Benny and Dawson (1983) and Stove (1985). Both were examined, compared and evaluated through their performance in mapping Derwentwater, both were successful in producing reasonably accurate depth information (Fig. 3.5). However, to my surprise, equally good was a regression based algorithm, which I had developed for Derwentwater. Most likely due to the integration of the local physical and environmental conditions into their structure. This research was considered to be significant at that time and was published in the *International Journal of Remote sensing* (Baban 1993b).

3.2.1.2 Water Resource Management

I was becoming interested in seeking ways to manage inflated sediment loads in river catchments due to the destruction of a protective vegetation cover through land clearance, and the widespread adoption of increasingly intensive agricultural practices. Clearly, suspended sediments in rivers, lakes and reservoirs can

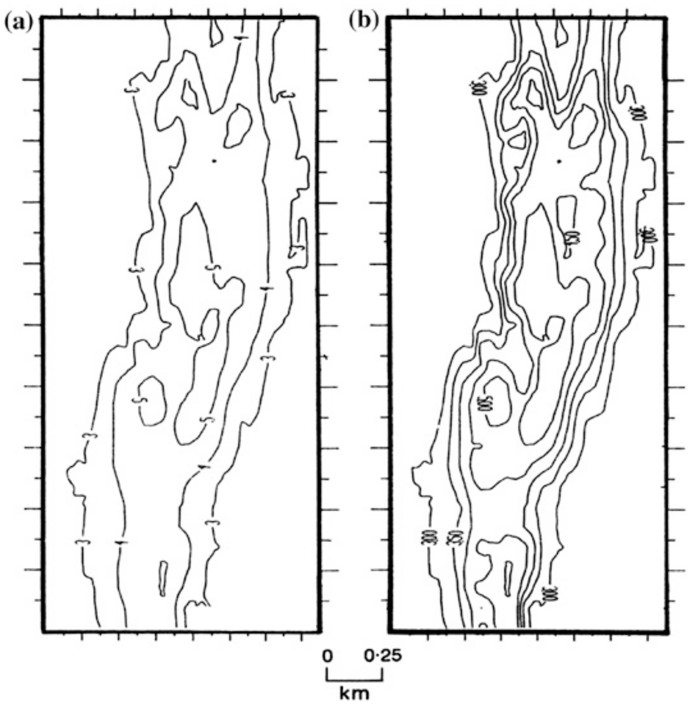

Fig. 3.4 A comparison between a thermal map developed using remotely images and the bathymetric for Constant lakes, UK

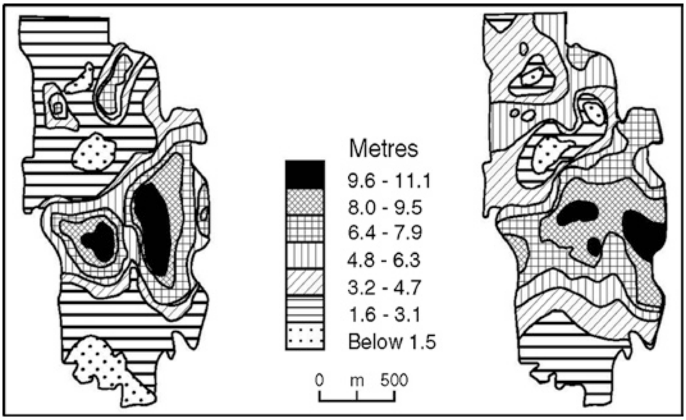

Fig. 3.5 Bathymetric maps for Derewentwater lake, UK using MSS4 and TM1 bands

influence water quality, primary production, fish production and the lifetime of water bodies. Furthermore, increased sediment loads can induce a range of environmental problems during the transfer and deposition of sediment away from the site of erosion. However, this work will require information regarding the spatial and temporal distributions of erosion vulnerable sites within catchments and sediment loads in water bodies in a region. Remote sensing techniques can provide information about areas prone to erosion and the subsequent sediment load in water bodies within a catchment area. This is usually based on the deduced spatial and temporal distribution of turbidity, suspended material and associated pollutants, acting as natural tracers.

In this research, I aimed to promote a holistic approach that takes into consideration the causes as well as the effects of soil erosion and water degradation problems, to understand hydrological processes in catchments using remotely sensed tracer information within a GIS framework. This objective was realised by first, illustrating the potential of using remote sensing techniques to estimate and map soil erosion related parameters and associated pollutants based on their behaviors as natural tracers in water bodies and their catchment areas. Secondly, using the remotely sensed tracer information within a Geographical Information Systems (GIS) framework to understand hydrological processes, to identify, locate and ultimately to minimise the effect of erosion vulnerable and potential pollution sites within catchments. Clearly, this approach can easily be used to promote a clearer conceptual understanding of hydrological processes and to develop, monitor and simulate management strategies aiming at minimising the magnitude of these problems within catchments. This potential was recognized by the participants in the International Association for Hydrological Sciences (IAHS) during my presentation and the subsequent publication of the research as a refereed chapter in a book (Baban 1999).

Having adopted the systems approach, I began to think about the possibility of balancing ecological and economic concerns and managing the conflicts created by multiple uses of lakes. An effective way of making informed decisions is to base them upon best available information and use an objective approach to anticipate the consequences of the decisions. Remotely sensed data can assist with accurately detecting, monitoring and mapping water quality parameters and water trophic/ecological status a well as opportunity to adopt a holistic approach, enabling lakes to be studied as an integrated system rather than individual entities. Hence, offering the ecological manager and environmental analyst great opportunities to obtain the necessary information. In this research I examined and evaluated the possibility of employing remotely sensed images to map the spatial distribution of water quality parameters in lakes (Fig. 3.6). The outcomes were very encouraged and published in the *International Journal of remote Sensing* (Baban 1993a).

My thoughts progressed towards evaluating the use of remotely sensed data and Geographical Information Systems to understand hydrological processes in catchments. Satellites are proven to be effective tools for detecting, estimating and mapping the distribution of suspended solids concentrations and turbidity in surface waters. This success is based on a number of factors including that water is spectrally unique and the existence of suspended solids and turbidity within the water seems to influence the optical characteristics of water and consequently, to act as a natural tracer. Based on my review, it became clear that the deduced spatial and

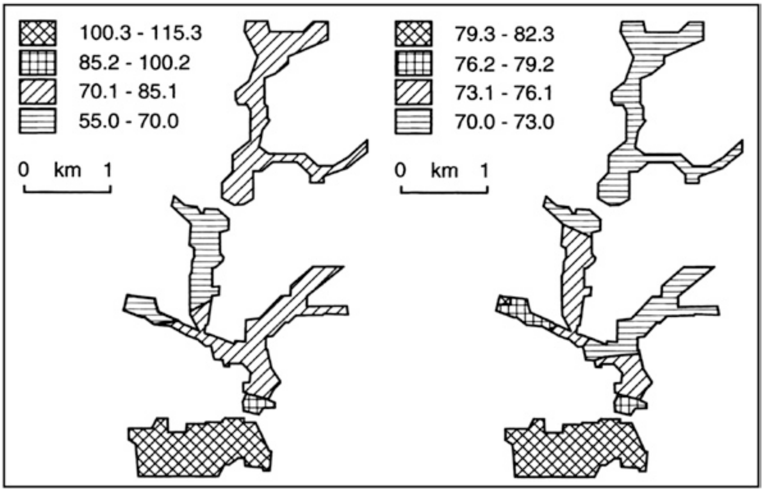

Fig. 3.6 Mapping Chlorophyll a and Total Phosphorus in the Trinity Broads, UK

temporal distribution of suspended solids concentration and turbidity, taking into considerations the influence of wind velocity and direction and tidal current conditions, it is possible to detect and map the following; flow directions, surface water circulation patterns, the transport and deposition of suspended solids, particle size distribution and mineral composition and the origin of suspended sediments in water bodies.

Although hydrologists have begun to recognize the power inherent in digital remotely sensed data some time ago, it was not possible to utilize it. Conventional hydrologic models are fed input data from conventional observation networks. Consequently, there is interdependency between *model structure* and *input data* formats. Therefore, the majority of existing hydrological models were not structured to take full advantage of the potential value of such data. In fact, the models were deliberately simplified in their original development because of the absence of the type of spatial and temporal information that modern remote sensing technology is capable of providing. I also indicated that developments in GIS made utilizing remotely sensed data possible. This can be achieved through interfacing hydrological models with a GIS that can accept input, amongst other formats, and produce output based on spatially distributed variables according to a grid based system. The GIS can further enhance the modeling process through providing functionality for constructing, testing, simulating and evaluating various management scenarios relating catchment process (data relating to soils, vegetation and non point sources within catchments can also be mapped using remote sensing) to water flow and quality in water bodies. This work was published as a refereed chapter (Baban 1999).

By this time, I was learning that most practicing engineers and scientists view hydrologic models as tools capable of providing the necessary quantitative description of hydrological processes required for water resources and water quality planning, and river engineering. Models should be robust, effective and easy to understand and use, yet complex enough to be representative of the system being studied. Flow models usually simulate steady-state, one dimensional flow: the quantities of flow are assigned, and water passage is ideal plug-flow with neither longitudinal dispersion nor lateral dispersion. These models are based on the assumption that the hydrological cycle is fundamentally the same in all drainage basins and the magnitude of parameters influencing runoff varies with climate, geology, soils and topography. Hence, concurrent stream-flow and climate records are required for calibration. Water quality models are usually developed to simulate a specific type of river-quality problem. Examples include simulating dissolved oxygen levels at various points along a river system. This is done by modeling the interactions of physical and biological processes affecting oxygen demand. These models are generally developed for steady-state flow regimes and assume that longitudinal dispersion is insignificant.

This understanding of the use of hydrological models motivated me and I became interested in modelling water flow and water quality in rivers, this desire was reinforced when concurrently, I was introduced to ISIS a relatively new and advanced conceptual deterministic hydrodynamic-water quality model. During 1996, Ian Foster and I were approached by the Environment Agency in the UK to develop a data management system for information acquisition and analysis as well as modeling water flow and water quality of the River Avon, UK. The River Avon is located in a lowland (<150 m AOD), predominantly agricultural area and has a mean annual discharge at Evesham of *c.* 15.2 $m^3\ s^{-1}$ (1310 MI day^{-1}) (Fig. 3.7). Over the past several decades, the River Avon basin has seen diverse and intensive urban growth together with agricultural development and intensification. In consequence, both water use and nutrient (N and P) rich waste discharges have increased substantially. Symptoms of accelerated eutrophication, including the growth of attached and planktonic algae, which lead to diurnal variations in dissolved oxygen concentrations, have characterised the main river and some of its tributaries.

In December 1992, the Avon and a major tributary, the River Arrow, were put forward as candidates for designation as "Sensitive Areas" under the EU Urban Waste Water Treatment Directive 1991. For designation as a sensitive area under the UWWT Directive, a watercourse must receive sewage effluent from "a qualifying Sewage Treatment Works (STW) discharge" serving a population of greater than 10,000 pe. Under this Directive, 1 pe is defined as the organic biodegradable load having a 5-day biochemical oxygen demand (BOD) of 60 g of oxygen per day. In 1994, 79 sites were selected for water quality sampling. These included 58 river sites, the five major qualifying STWS, 13 minor STWs and three reservoirs/lakes. The qualifying STWS, main River Avon sites and major tributaries were sampled at weekly intervals; minor STWs and smaller tributaries were sampled fortnightly and the remaining sites were sampled at monthly intervals. On-site determinations were made of pH, redox potential, dissolved oxygen (mg 1^{-1} and % saturation), temperature and river discharge. Sub-samples were filtered on site through 0.45 μm membrane filters, and 11 water quality determinants were measured in the laboratory within 2 days of

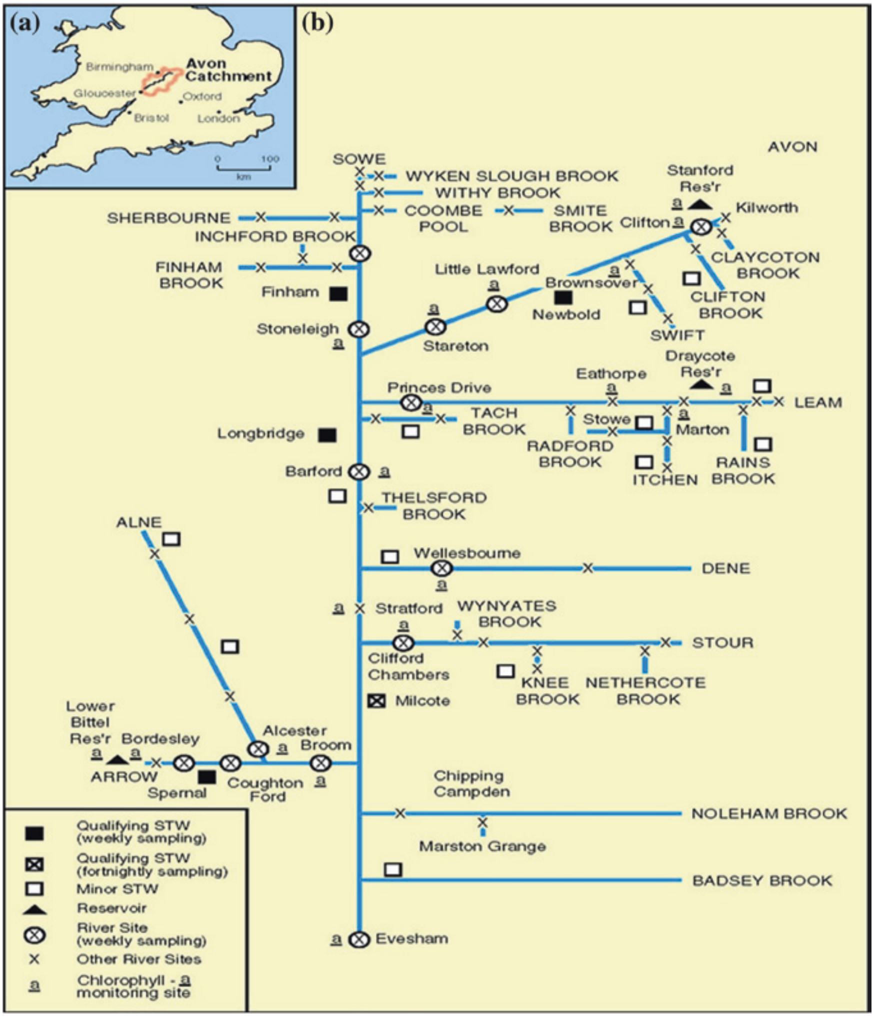

Fig. 3.7 A diagrammatic representation for River Avon, UK (Baban and Foster 2002)

sample collection. These measurements included suspended solids, BOD, COD, Kjeldahl-N (unfiltered), Total P (unfiltered), Total P (filtered), ammonia (filtered) TON (filtered) orthophosphate (filtered), orthophosphate (unfiltered) and chlorophyll a (the latter was measured additionally at 19 stations, including three reservoirs, with sampling from April to September in the first monitoring year only). All laboratory analyses were undertaken at the Environment Agency laboratory in Nottingham, UK.

In this research, the ISIS model was used to simulate flow in the Warwichshire River Avon under a range of flow conditions (Fig. 3.7). ISIS was also used to assess the impact of flow on water quality under each flow condition. The model consists

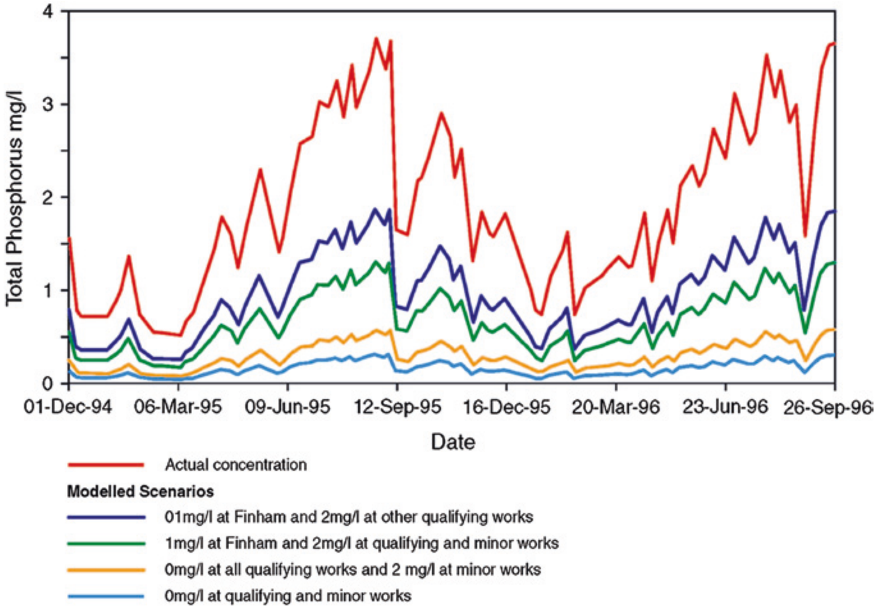

Fig. 3.8 Actual and modeled Total phosphorous, River Avon, UK (Foster et al. 1997a)

of two components, ISIS-Flow and ISIS-Quality. ISIS-Flow was found to accurately predict flow variations at two stations (Warwick and Stratford) located on the river network. ISIS-Quality output provided a reasonable outcome in terms of predicting DO, BOD, Total Nitrogen, Ammoniacal Nitrogen and Nitrate-N. A sensitivity analysis for ISIS-Quality revealed that only changes in the temperature dependency factor and nitrogen decay parameters had a significant impact on the predicted output of the Dissolved Oxygen module. Evaluations regarding the user friendliness of the model, as well as specific evaluations regarding the ability of the model to predict water quality in the Avon, were also presented. This research was published as a Journal paper (Baban and Foster 2002). The water quality components of the project in terms on Nutrient Concentrations and Planktonic Biomass (Chlorophyll *a*) Behaviour in the Catchment of the River Avon. This work was presented in international conference and published as eferred chapter within *IAHS publications* (Foster et al. 1997b) (Fig. 3.8). Furthermore, the issues related to Sediment-associated Phosphorous transport in the Warwickshire River Avon were published as a refereed chapter in a book (Foster et al. 1996d). This research produced a significant consultancy report in two volumes for the sponsor; The Environment Agency, Severn-Trent Region, UK. Both volumes focused on the Sediment-associated Phosphorous transport in the Warwickshire River Avon, UK (Foster et al. 1996a, b). Three reports were produced; these were dealing with the process and, the outcomes from Hydrodynamic and Water Quality Modelling, using ISIS Flow and ISIS Quality, to evaluate the impacts of Extending Navigation on the Upper Avon (Foster et al. 1996c; Baban et al. 1997). Two final reports were produced for the sponsor, these dealt with the issue of Eutrophication in Controlled Waters in Lower Severn Area (Foster et al. 1998a, b). These activities were sponsored by the *Environmental Agency, UK*, as a project focused on researching Avon Eutrophication (entitled: Avon Eutrophication II), and by *the Higher Education Funding Council 'CollR Initiative', UK* for a project entitled: Fine Particulate Sediment Transport in the Upper Avon, Warwickshire: Multi-tracer Source Modeling.

3.2.2 Coastal/Marine

Having visited Breydon Water Estuary on regular basis on my way to the beach, I often wondered about the possibility of using remotely sensed data for mapping fluvial sediment discharge from rivers into coastal waters. Often the turbidity seen near river mouths is due to large quantities of suspended sediment carried into the sea by contributing streams. The dense and coarse sediments tend to be deposited first, nearest to the river mouth. Turbidity and suspended solids act as a natural tracer detectable by Landsat reflective bands. This attribute, in combination with the synoptic view and frequent coverage, makes Landsat data ideal for use in coastal environments. Landsat can provide data on sediment volume, characteristics and areas of deposition. Knowledge of the horizontal and vertical distribution of sediment as well as the nature and particle sizes of suspended sediments in coastal water is important for civil engineering works aimed at protecting beaches or harbours. It was my judgment that the various detection wavelengths in the remotely sensed imagery are capable of providing this information.

In this research, I examined the sediment discharge of the river Yare via Breydon water estuary into the North Sea using Land-sat TM reflective bands. The spatial distribution of suspended solids as well as the spatial and vertical extent of different turbidity levels were detected, estimated and mapped (Fig. 3.9). Based on this information the water circulation pattern at the mouth of river Yare was identified and mapped.

The influence of wind velocity and direction, as well as the tidal current conditions prior to and during the image time, on turbidity and water circulation patterns were examined. The tidal influence was found to be the most significant factor in shaping and guiding water circulation near the mouth of river Yare. This research was published as a research paper in the *Marine Geology, International Journal of Marine Geology, Geochemistry and Geophysics* (Baban 1995).

3.3 Water Resource Science and Management in Malaysia

My observations and research experience in Malaysia indicated that in tropical regions undergoing rapid development, lakes/reservoirs can suffer from significant sedimentation and water quality degradation problems. Therefore, when planning

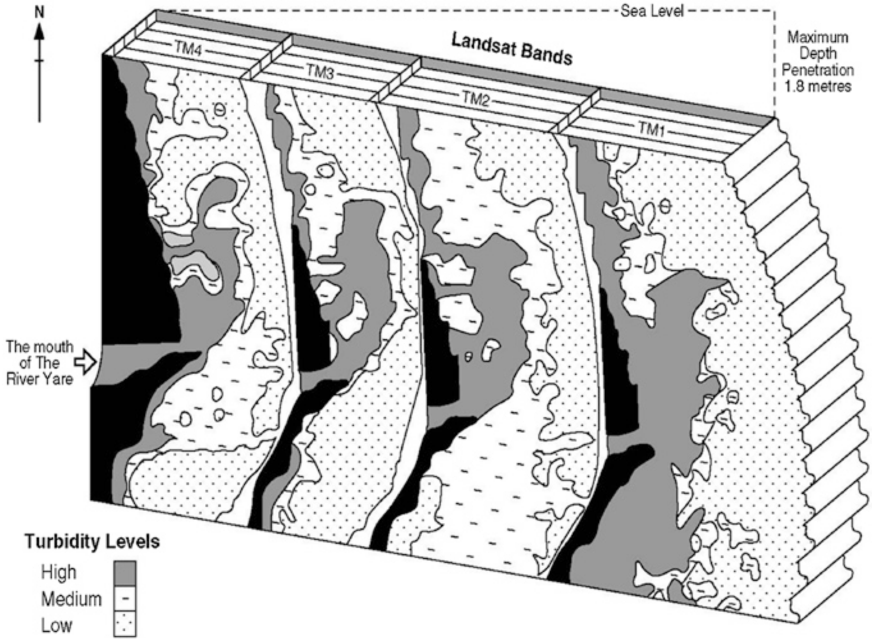

Fig. 3.9 The horizontal and vertical distribution of turbidity levels in the mouth of river Yare (Baban 1995)

reservoir sites, particular attention should be given to managing upstream soil erosion and downstream sedimentation. This information can be used to develop and validate predictive models of circulation patterns. These models will provide information on the potential paths which might be followed after, for example, accidental discharge of oil or chemicals into the coastal area. In this research, I developed and simulated the effect of several hydrological catchment management scenarios such as *deforestation and level terracing* on twp proposed reservoir sites on the Langkawi Island (Fig. 3.10). The outcomes indicated clear options for reducing the potential soil erosion and also indentified the impacts of elevation and slope on soil erosion rates. This study has provided managers with informed and clear options for making decisions to prolong the life of reservoirs at their full capacity. Aspects of this research were published as part of the conference proceedings of the *20th Asian Conference in Remote Sensing*, which was held in Hong Kong (Wan-Yusof and Baban 1999) and the Proceedings of the *20th Conference of Asian Federation of Engineering Organisations (CAFEO),* held Cambodia (Wan-Yusof and Baban 2002a) and a more comprehensive version was published as a research paper in the *Asian Journal of Geoinformatics* (Baban et al. 2003).

I was also involved in using Remote sensing and GIS for identifying and locating suitable sites for locating reservoirs to meeting the increased demands for water on the Island. In this research, a criterion was developed and implemented to locate

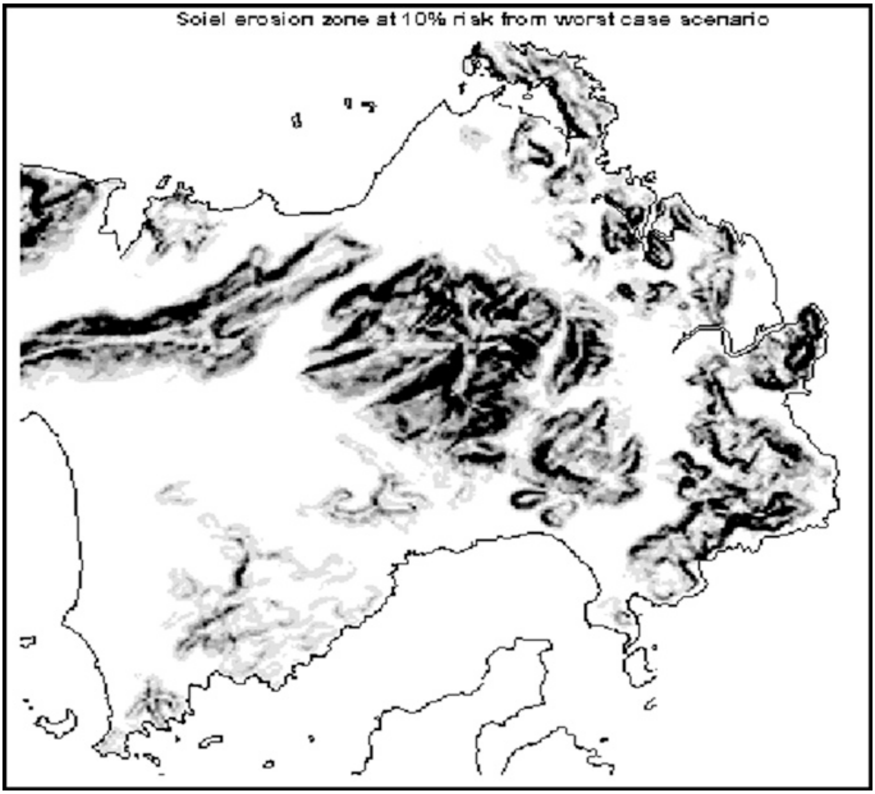

Fig. 3.10 Using USLE within a GIS framework to develop soil erosion scenarios. (Baban et al. 2003)

potential sites for the reservoirs based on suitable topography, geology, hydrology, land use/cover types and settlements. Satellite imagery and digitized geological and elevation maps were utilized to generate the necessary data layers for the developed criteria. Then GIS was employed to implement the criteria using the Weighted Linear Combination (WLC) method. The outcomes (Fig. 3.11) produced five sites with the 70 Mld water capacity, three of which matched those of a previous field study. Whilst for the 90 Mld water requirement, two potential sites were produced and both have matched those of the field study. The outcomes indicated that the developed criteria were sensitive to physical, environmental and economical settings on the Langkawi Island. Furthermore, GIS and remote sensing can be useful tools for generating, manipulating and handling relevant data layers and ultimately providing management options for decision makers. This effort was presented and later published in the *Proceedings of the 21st Asian Conference on Remote Sensing,* held in the National Central University, Taiwan (Wan-Yusof and Baban 2000), the *Proceedings of the 19th Conference of Asian Federation of Engineering Organisation (CAFEO,* held in Brunei Darussalam (Wan-Yusof et al. 2001), the

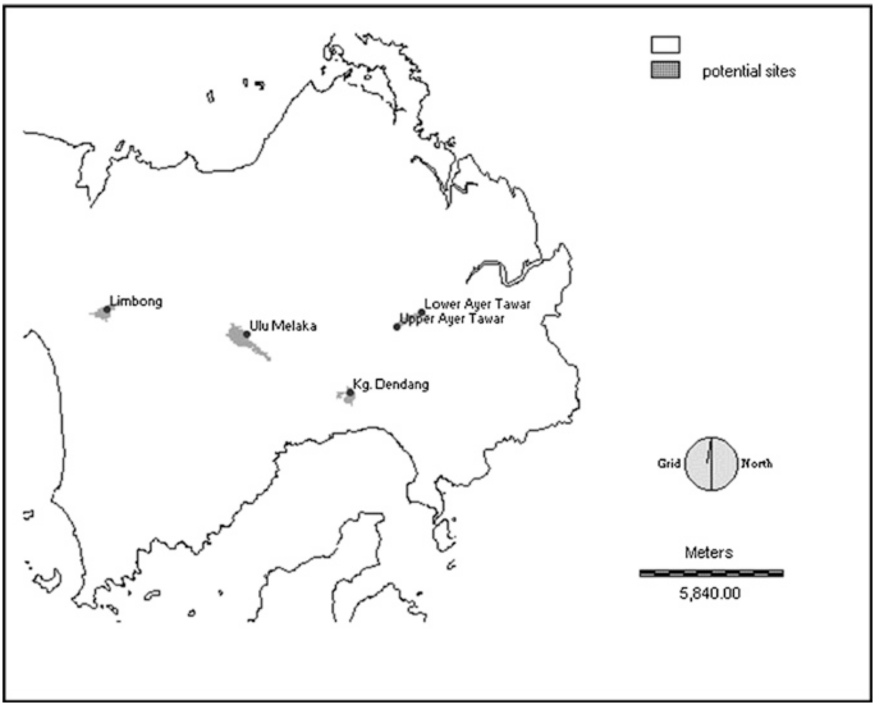

Fig. 3.11 Potential reservoir sites with 70 Mld water capacities using the Weighted Linear Combination (WLC) method (Baban and Wan-Yusof 2003)

proceedings of the second world Engineering Congress in Malaysia (Wan-Yusof and Baban 2002b), and later in a more comprehensive form as a research paper in the Journal of *Water Resources Management* (Baban and Wan-Yusof 2003).

3.4 Water Resource Science and Management in the Middle East

In the Middle East water resources are limited, and are currently decreasing, whilst the demand for water consumption is increasing for reasons such as the expanding industrialisation and population growth. This combination makes the distribution of this limited resource very difficult and potentially explosive. In fact a recent investigation by the centre for strategic and International Studies in Washington, DC, concluded that the situation is likely to become so acute that, in the near future, water—not oil—will be the dominant resource of the Middle East (Star and Stoll 1988). This prediction is most likely to be realised for three major reasons. First, for geopolitical reasons; since water resources are not restricted by international boundaries. An examination of the recent history of the region indicates that the race to develop water resources has already started. Many upstream countries in the Middle East have drawn up plans to divert shared river and aquifer water supplies to fill reservoirs and irrigation systems in order to increase agricultural production. For example Syria is planning to divert water from the Yarmuk River, Turkey from the upper Euphrates and Tigris, Libya from its shared aquifer and Ethiopia from the Blue Nile (Clark 1991). To date many of these plans are being implemented. Secondly, natural problems hinder the full use of the available water resources in the region. For example most of the lakes and reservoirs in the Maghreb States of North Africa suffer from sedimentation problems. Consequently the increase in water demand over time will be associated with a diminished storage capacity (Bouzaiane 1991). The third problem is the weaknesses of the decision-makers. Some managers may have a poor general knowledge of the problem due to their appointment for political reasons (Perera and Tateishi 1995). Consequently and for obvious reasons, the decision making process becomes subjective rather than objective. Water resources in the Middle East, are therefore likely to dominate the headlines for some time to come. In order to actively promote political and social stability, minimise the damage and strike a balance between environmental and economic concerns, water managers and decision makers should use every aid available to them as they attempt to mange their limited water resources. They will also need the ability to reflect upon, and anticipate, the consequences of their decisions. The sections below summarise my contributions to this objective.

3.4.1 Tunisia

The reservoirs in the Maghreb states of North Africa are suffering from significant sedimentation and water quality degradation problems. These are mainly due to the effects of climate, increasing population pressures and growth in industrial and agricultural development.

In this research, I argued that attempting to effectively manage reservoirs in the Maghreb States of North Africa, examining Tunisia as a case study, will depend on a clear understanding of the hydrological processes involved, in addition to adopting a comprehensive approach which takes into account the causes as well as the effects of sedimentation and water quality degradation. A methodology for reservoir management was presented using ground referenced data, remotely sensed data and GIS. This approach will enable resource managers to target their limited financial resources in those areas which contribute most to these problems and to plan and allocate the scarce water resources effectively. This research was presented in and later published in the *proceedings of the Satellite-Based Observation: A Tool for the Study of the Mediterranean Basin Conference* (Baban 1998).

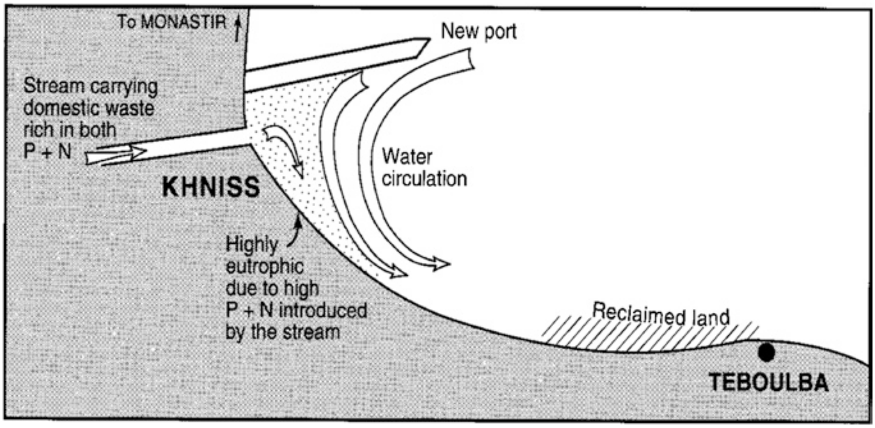

Fig. 3.12 Managing environmental degradation due to domestic waste water discharge in the Kniss coastal area (Baban et al. 1999)

In terms of coastal management, the water at Khniss beach in Tunisia (Fig. 3.12) suffered from eutrophication caused by domestic waste rich in both phosphate and nitrate being added to the coastal water through a stream. The construction of a new port, which obstructs water circulation (Fig. 3.12), compounded the problem and accelerated the decay in this section. A simulation programme in 1995 for the section indicated that water depth is a controlling factor in water circulation and the minimum required depth is about 0.5 m. The environmental authorities implemented a programme to fill in the shallow parts and deepen the rest of the area in order to maintain water levels at the minimum required depth to induce healthy water circulation (EA, personal communication). My repeated field visits to this site and observations indicated a continuous improvement of, and a visible management of the eutrophication problem at this site; however, the observations also indicated that the problem was exported further down the coastline. This work and some other case studies were published in the *Journal of Sustainable Development* (Baban et al. 1999).

3.4.2 Jordan

My association with Jordan started during early 1990s, I was invited to assist with developing remote sensing and GIS capabilities at Al al-Bayt University by the University President, then Professor Adnan AL-Bakhit and Professor Nadhir Al Ansari the Director for Strategic Water Resources Centre at the University. Then, during my visits, I realised the true significance of the water scarcity problem in Jordan as this resource is decreasing, whilst the demand for water use is increasing to sustain industrialisation, agricultural expansion and population growth.

Fig. 3.13 Working with Colleagues from Al al bayt University, Jordan, 1991–1994 as well as activities and outcomes; Binational Conference, *bottom right* and a Published book, *bottom left*

Groundwater is considered to be the major water resource. The Azraq is one of the largest groundwater basins and it is currently facing a serious over extraction problem. My activities in Jordan, a combination of research and postgraduate projects, examined several issues including; mapping ground water, assessing ground water vulnerability and estimating Nitrate leaching to groundwater (Fig. 3.13).

One of my research projects focused on discovering which Groundwater areas are most vulnerable and has the greatest potential for groundwater contamination based on hydrogeological and human impacts. Hence, I used Geoinformatics to develop groundwater vulnerability to pollution maps for the Azraq basin in Jordan. In this work, all of the major geological and hydrogeological factors that affect and control groundwater movement into, through, and out of the study area in the northern Badia region of Jordan were incorporated into the DRASTIC model. Parameters included; depth to groundwater, recharge, aquifer media, soil media and topography. The hydraulic conductivity of the aquifer was not included in calculating the final DRASTIC vulnerability index for potential contamination due

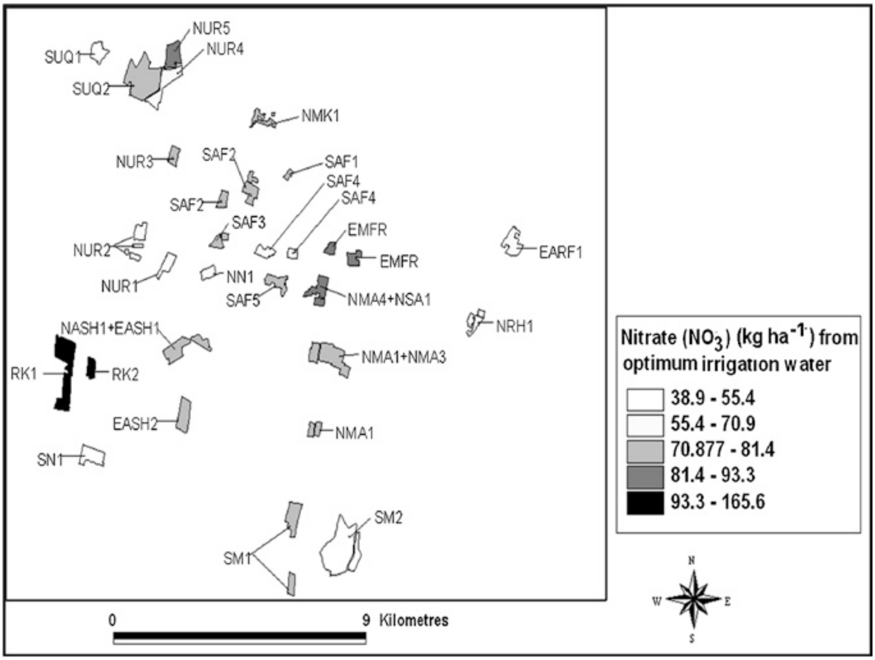

Fig. 3.14 Estimated nitrate mass added to the soil from the use of irrigation water (April 2000–Dec. 2000) (Baban 2008)

to a lack of sufficient quantitative data. GIS was used to create a groundwater vulnerability map by overlaying the available hydrogeological settings. The resulting vulnerability map was then integrated with a land use map as an additional parameter in the DRASTIC model to assess the potential vulnerability of groundwater to pollution in the study area (Fig. 3.14). The final DRASTIC model was tested using hydrochemical data from the aquifer. The outcomes indicated that in areas with limited secondary data, DRASTIC can provide important objective information that could be used to inform local decision-making. This research was published in the journal of *Applied Geography* (AL-Adamat et al. 2003).

Another project focused on examining groundwater resource in the Azraq Basin using GIS (Fig. 3.15). The two essential thematic layers of the depth to groundwater and groundwater level were created. The relationship between land topography and depth to water surface was found to be statistically significant, whilst there was no significant association between land topography and groundwater level. Furthermore, the slope of groundwater level was mapped; the majority of the study area has a slope of less than 4° with smaller scattered areas were the slope could rise up to 9.5°. The outcomes from this research can be used for groundwater monitoring, planning as well as testing the effectiveness of various management scenarios. The results indicate that, due to the nature of the data involved and the analysis required GIS could facilitate the necessary

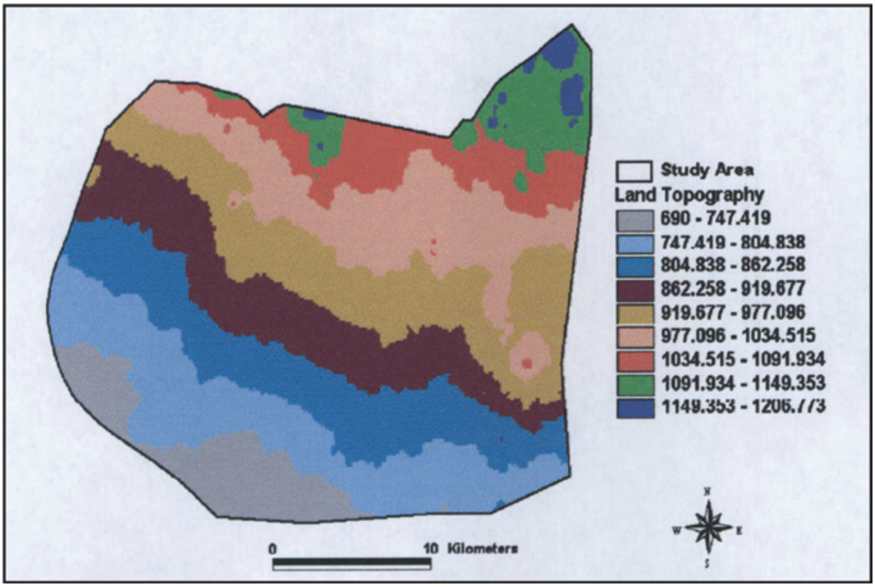

Fig. 3.15 Examining groundwater resources in the Azraq basing, Jordan, using GIS (Baban 2008)

spatial digital analysis. Using GIS will also make it possible to simulate potential fluctuations in groundwater levels in critical locations due to external factors such as future climate changes. This research was published in the *Surveying and Land Information Science Journal* (AL-Adamat and Baban 2004). Another aspect of this project dealt with estimating Nitrate leaching into groundwater in the Azarq Basin. GIS was used to estimate nitrate leaching to groundwater from cesspools and agriculture. Estimated leaching from cesspools ranged from approx. 800 to 1,990 kg year-1 (approx. 0.3–0.7 kg per household per year). The estimated loss from agricultural land was from approx. 222,600 to 358,800 kg year-1. In Jordan, water resources are scarce and are being degraded, while the demand for water use is increasing. The study indicated the urgent need to manage the expansion of agriculture in the region and it was published a refereed chapter in a book (Baban et al. 2006).

A further project examined Rainfall Trends in the Jordanian Badia Region. In Jordan, like other semi-arid countries in the region, water resources are increasingly becoming an important factor in the stability, the growth and national security. This study examined the rainfall record in 25 stations for the period 1967–1995 to determine periodicity and interrelation between the stations using power spectral, harmonic analysis and correlation coefficient techniques. The ARIMA model is used to forecast rainfall trends in individual stations up to the year 2020. The outcomes show that the intensity of rainfall has been decreasing with time since 1967 and this trend will continue into the future. The average annual rainfall is relatively

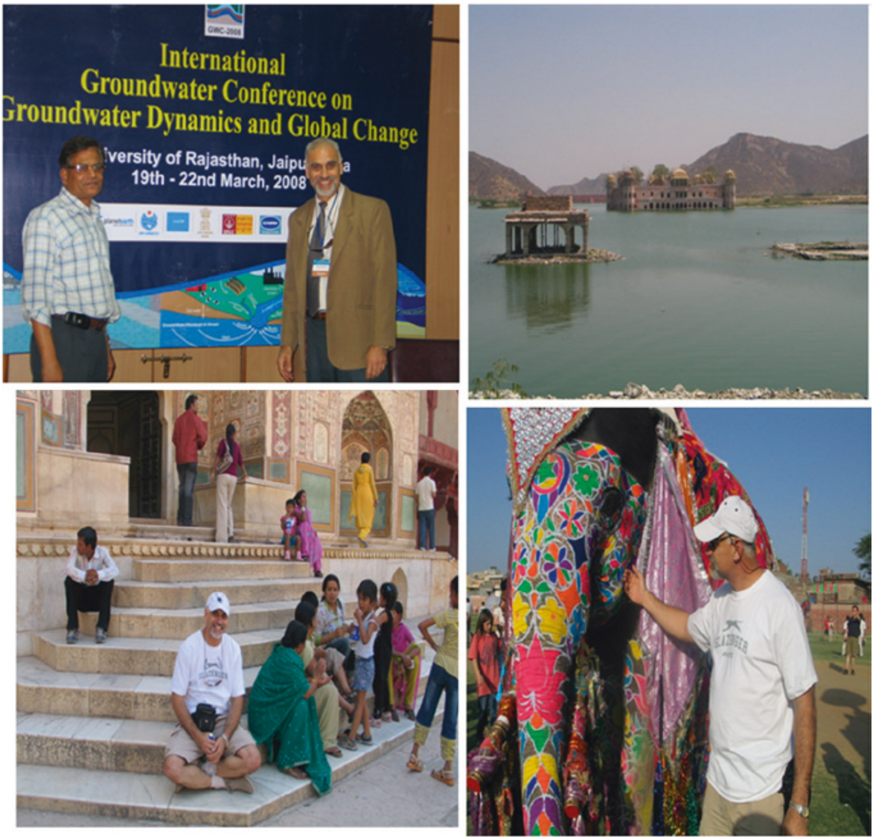

Fig. 3.16 The international groundwater conference, groundwater India 88, March, 2008, University of Rajasthan, Jaipur, Rajasthan, India

low (90 mm/y) and there are some significant differences in rainfall values between the stations determined mainly by topography. Stations having the same altitude and close geographically tend to have a strong statistical association and show a similar rainfall trend. An investigation into using remotely sensed data to estimate rainfall intensity showed a statistically significant relationship between vegetation index and rainfall intensity. The outcomes from this study can be used in developing the basis for future planning in agricultural, economic and social development in Jordan and in the Badia region in particular. This research was published in the *Surveying and Land Information Science Journal* (Al-Ansari and Baban 2005). A comprehensive paper dealing with the issues of irrigated agriculture, development and sustainable ground water usage in the Badia Region of Jordan was presented and later published in the proceedings of the International Groundwater entitled Groundwater India 1988 (Baban 2008) (Fig. 3.16).

In collaboration with Professor Al Ansari of Al al-Bayt University, I organized a bi-national Jordanian and British conference on managing water resources in the

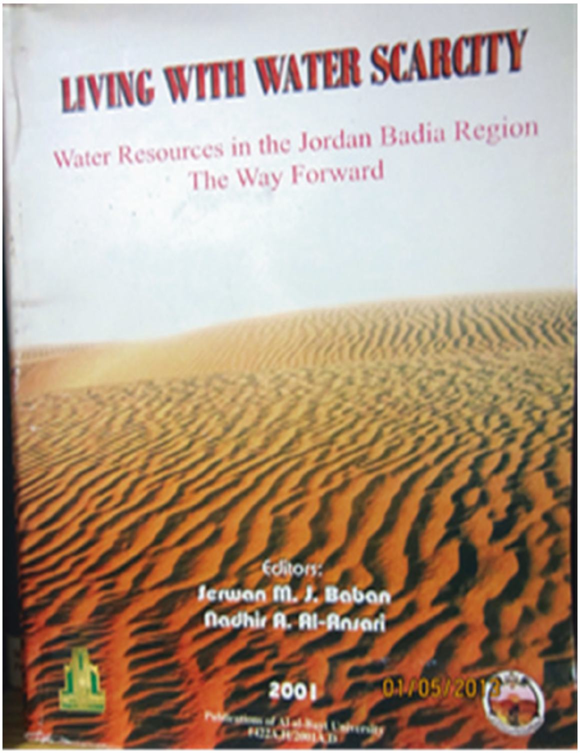

Fig. 3.17 An edited book by Baban and Al-Ansari dealing with managing water scarcity

Badia Region during July 1999 (Fig. 3.13). Selected papers from the conference and invited papers by water experts formed the contents of a book entitled "Living with Water Scarcity; Water Resources in the Jordan Badia region, The Way Forward". I had the pleasure of co-editing this book with Professor Al Ansari (Baban and AL-Ansari 2001) (Fig. 3.17).

3.4.3 Iraq

Based on an ongoing theme of examining the potential applications of Satellite remote sensing and GIS in maximising the use of water resources in the Middle East, I focused on Iraq as a case study. Iraq was chosen for several reasons. First, Iraq is one of the most northerly Arab countries and will represent the worst possible scenario for cloud cover throughout the year. Secondly, water shortages in Iraq have parallels in almost every other country in the region. Thirdly Iraq is likely to be faced with a unique water shortage scenario in the future and SRS and GIS might help to minimise the potential hazards and possible damage.

This research attempted to illustrate the potential and pitfalls of employing SRS and GIS in maximising the use of water resources in the Middle East. To have a focus, Iraq has been selected as a case study in order to demonstrate the relevance and applicability of each potential application. Based on the success of these applications information system/GIS is proposed to store, integrate, manage and analyse data relating to water resources. The proposed management system will use SRS as an information source and GIS as an analytical tool within the management system. The system will enable decision makers to extrapolate, predict, update, plan, evaluate, compare, simulate and visualise various management actions and to anticipate the consequences of implementing each action over different periods of time in an objective manner, ultimately enabling them to optimise management decisions. This research was presented in an international conference and was published as a chapter in *IAHS Publications* (Baban 1997).

As Southern Kurdistan is most likely to be faced with a unique water shortage scenario in the future due to activity in the neighboring countries making the distribution of this limited resource very difficult and potentially explosive. In order to actively promote political and social stability, sustainable development and environmental safety, water managers and decision makers should use every aid available to them as they attempt to best mange their limited water resources. They will also need the ability to reflect upon, and anticipate, the consequences of their decisions.

In this research, I developed a Geoinformatics based approach to manage water resources in Southern Kurdistan. In this research I examined the applicability of Geoinformatics as a water resources management tool in Southern Kurdistan and the relevance and the potential success of a range of applications, including water supply, hydrological catchment management, and managing sedimentation in reservoirs, floods and agriculture are examined. Based on the outcome of these assessments a Geoinformatics based hydrological management system is proposed. This management system uses Remote Sensing as an information source and GIS as an analytical tool within the management system (Fig. 3.18). The system will enable decision makers to extrapolate, predict, update, plan, evaluate, compare, simulate and visualise various management actions and to anticipate the consequences of implementing each action over different periods of time in an objective manner, ultimately enabling them to optimise management decisions. The examination and analysis indicated the suitability of Geoinformatics for managing water resources in southern Kurdistan. Providing that the following aspects of the Satellite imagery are suited for the application(s) of interest; spatial resolution, spectral resolution, radiometric resolution and temporal resolution as well as having cloud free skies. Encouraging factors for using Remote Sensing in this region include; having simple agricultural schemes, limited amount of pollution and the public ownership of water resources. This research was published in the *International Journal of ZANIN* (Baban 2006).

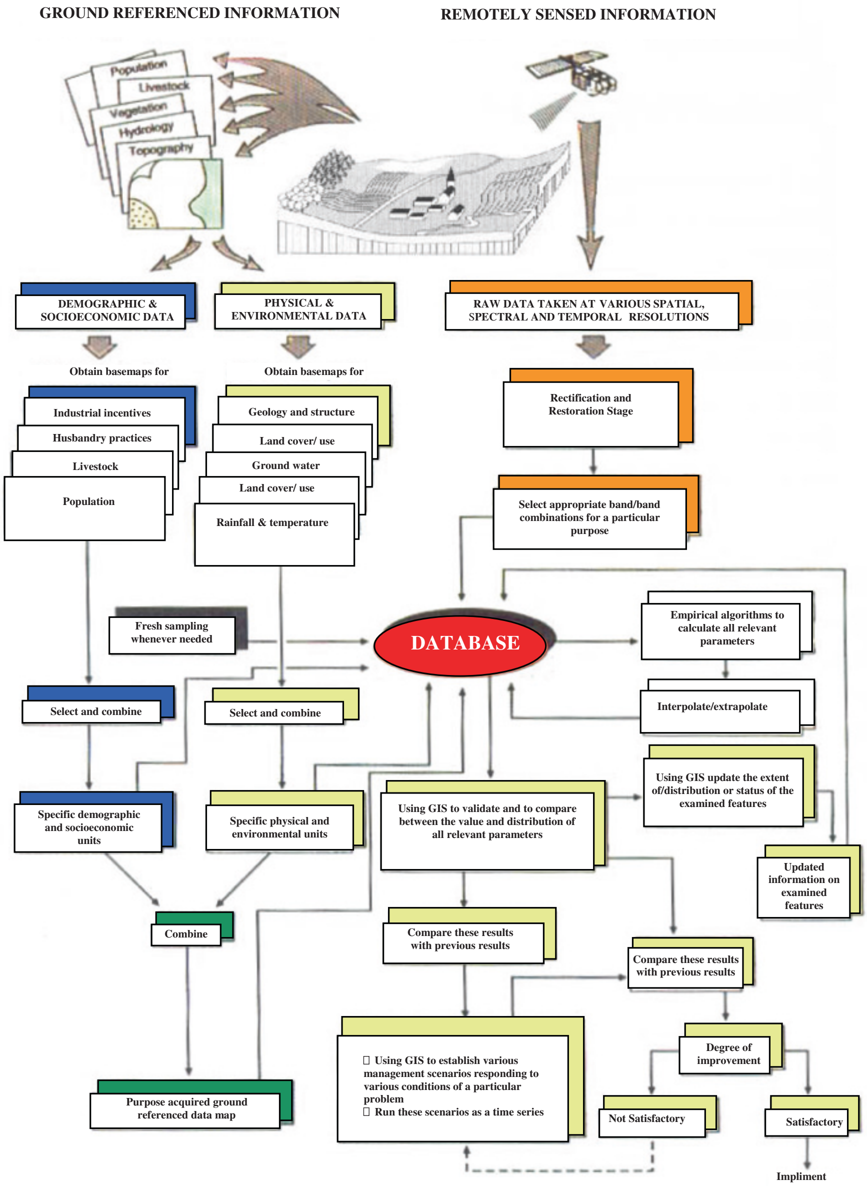

Fig. 3.18 The proposed watershed system for Kurdistan region, Iraq (Baban 2006)

Once, I assumed by duties as the Minister of Agriculture and Water Resources, I focused my research on issues dealing with the challenges and opportunities surrounding the questions of water sufficiency and security in Kurdistan Region

Fig. 3.19 Presenting in Several national and international conferences. **a** Delivering the Keynote speech in London Conference, 2012. **b**. Presenting the Keynote speech at Iraq water 2013 Conference, Turkey. **c** Presenting in the Kurdish World Congress, 2013, Sweden. **d** Presenting the international cooperation conference, 2013, Turkey

and produced a Road map charting the way forward. These were presented in and international workshop in London, UK (Baban 2012) (Fig. 3.19) and in a Bi-national conference called *Water Iraq Summit 2013* in Turkey (185) (Fig. 3.20). Then focused on developing a 5 year strategic plan for the Ministry (Baban 2013a, b). Later through a reflective process the implementation of the Road map over the period of 12 months and linking Ministry work and thinking to regional and international cooperation platforms. These efforts were presented in and international conference in Sweden (Baban 2013c) (Fig. 3.19) and in another international conference dealing with promoting regional and international cooperation (Baban 2013d) (Fig. 3.19). A significant part of my work in the Ministry has focused on building dams (Fig. 3.20) to store the necessary water for the nation and building irrigation projects to benefit from the stored water for agriculture.

Fig. 3.20 Laying the foundation for a large dam by the Kurdistan Region Prime Minster

3.5 Water Resource Science and Management in the Caribbean

Despite being on a major route for oil and gas tankers, the Caribbean region did not have reliable models for Contaminant Transport and Water Circulation for the Intra-American Seas. This issue concerned me as the Intra-American Seas (IAS) consists of a number of small islands with high coastline to area ratios. These coastal areas often support the majority of an islands population, are utilized for various socio-economic activities and provide habitats for unique, fragile ecosystems. The islands and the juxtaposed landmasses that make up the Caribbean Region are interconnected by the water bodies that surround them. Interaction with coastal sea processes generated by the surrounding waters can pose a potential threat to the sustainability of these systems by providing a medium for the transport of contaminants introduced by accidental spillage, unregulated dumping and river discharge. This research examined water circulation in the IAS to identify the regional processes and characteristics that contribute to the dynamics of water circulation (Fig. 3.21). The management of tropical coastal environments and the use of emerging technologies for this purpose became an interesting challenge for me; hence, it was explored, examined and published in the *West Indian Journal of Engineering* (Al-Tahir et al. 2006). The issue of coastal management was also examined from the public perspectives and published in national Conference (Richardson and Baban 2004).

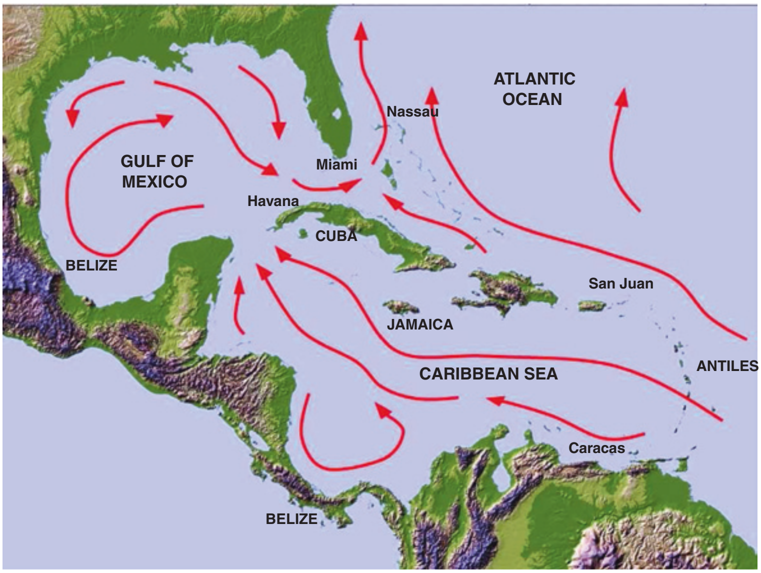

Fig. 3.21 Water circulation in the Caribbean region (Baban and Jules-Moore 2005)

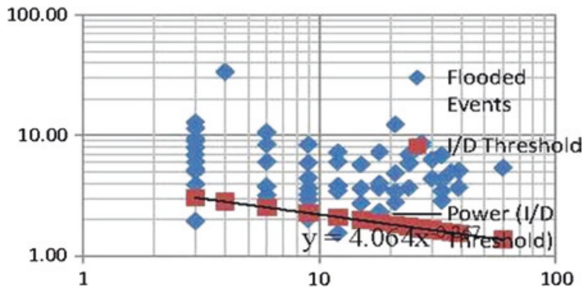

Fig. 3.22 The Intensity Duration threshold for rainfall events which resulted in floods during 2004–2008 (Pathirana et al. 2010)

Seasonal and inter-annual variations in tidal regimes, currents, air and sea surface temperatures in addition to bathymetry all seem to contribute to the observed circulation and dispersion of the waters contents. The identified processes were then used to inform the evaluation of a number of existing circulation models for the IAS. A number of circulation models exist that can generally be adapted for the region with some modifications and limitations, however the POM and NRL/NLOM were identified as being most relevant. The capabilities of these models in terms of their computational methodology to determine the influence of regional characteristics on the transport of contaminants have been evaluated to determine potential limits to their operations as they relate to the Region. This research was published in the *West Indian Journal of Engineering* (Baban and Jules-Moore 2005). I was also involved with developing predictions for rainfall using near real time satellite rainfall data (Pathirana et al. 2010) (Fig. 3.22) and early warning systems for managing landslides and floods in the Caribbean region (Baban and Aliasgar 2008a) (Fig. 3.23).

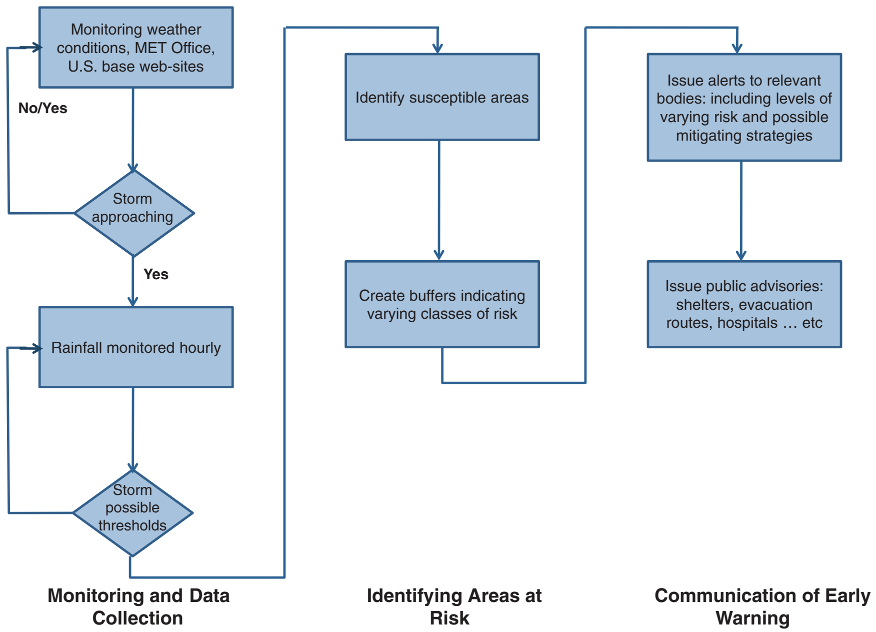

Fig. 3.23 A proposed basic early warning system for Tobago (Baban and Aliasgar 2008b)

The long chain of Caribbean islands surrounded by the Atlantic Ocean is annually devastated by hurricanes. The twin island Republic of Trinidad and Tobago is no exception to this and like its neighbours', spends millions annually, in recovery efforts. In July 2005, during my residence in the Caribbean, the Region was subjected to Hurricane Emily which resulted in debris flows in the Northern Range in Trinidad. Our research team has responded by developing a deductive approach by defining and summarizing the conditions making an area vulnerable to Debris flows. We examined the procedures used to examine rainfall intensity/duration thresholds and the contributory factors to these debris flows. Using Geoinformatics, it was possible to obtain geographical locations, identify catchment characteristics and to determine the conditions of susceptible slopes along roadways. This can be useful for planning future road construction and in identifying other susceptible roads in the Northern Range, if similar rainfall thresholds are met or exceeded. The research (Pathirana and Baban 2008) was presented in the 2nd International Conference of GIS/RS in Hydrology, Water Resources and Environment (ICGRHWE'06) and the 2nd International Symposium on Flood Forecasting and Management with GIS and Remote Sensing (FM2S'06). This was held during September 2007 in Guangzhou and Three Gorges, China. Later on, the research in a more comprehensive form was published in the *Journal of Disaster Advances* (Pathirana and Baban 2008) (Fig. 3.24).

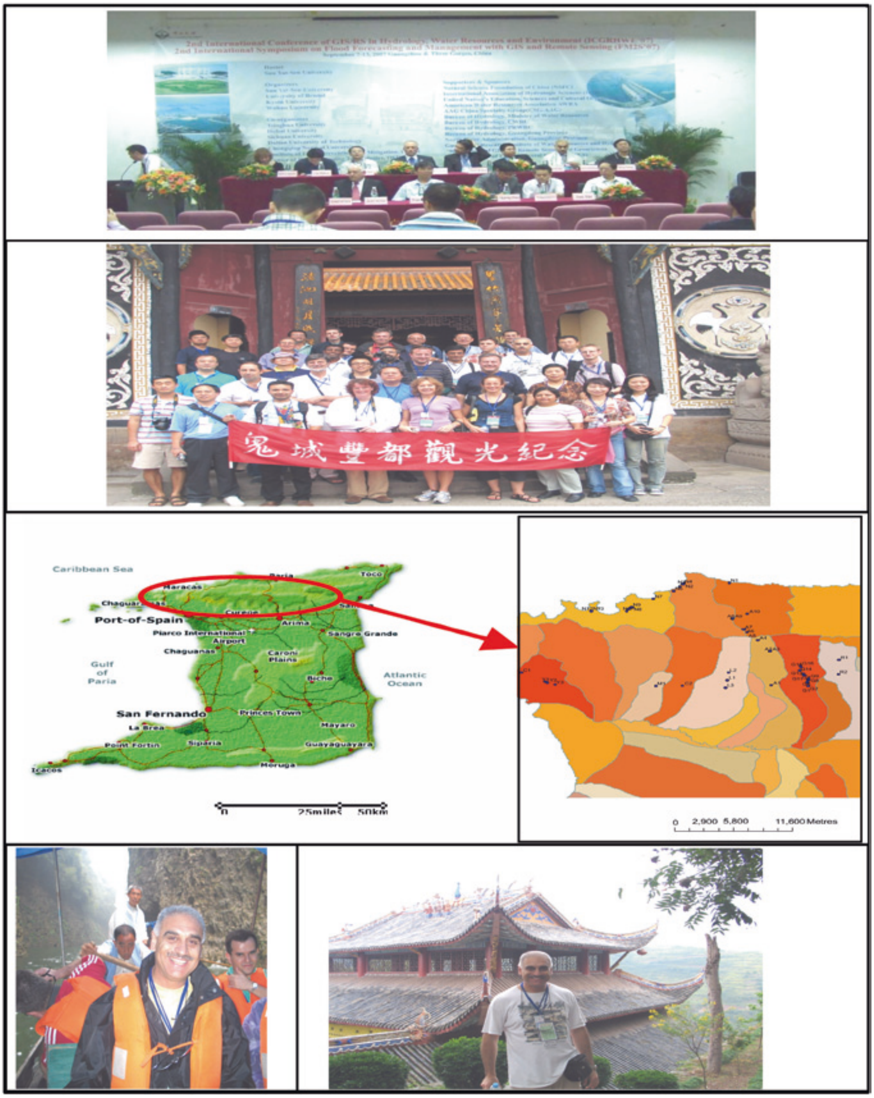

Fig. 3.24 Spatial Distribution of Debris Flows occurred during Tropical Storm Emily and various activity in 2nd International Conference of ICGRHWE'06 and the 2nd International Symposium on Flood Forecasting and Management with GIS and Remote Sensing (FM2S'06), September 2007, Guangzhou and Three Gorges, China

3.6 Water Resource Science and Management in Australia

Coral reefs are highly dynamic and productive marine ecosystems, providing habitat and refuge for an enormous number of species including corals, fish, invertebrates and algae. With increased anthropogenic pressures and global climate/environmental

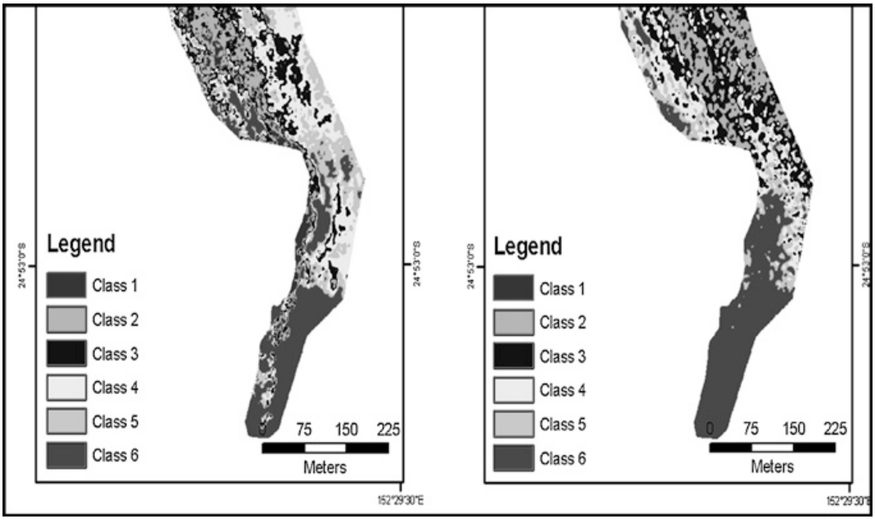

Fig. 3.25 Mapping coastal and marine habitats in Australia using remotely sensed imagery. (Baban et al. 2008)

change, many coral reefs are rapidly declining. Fringing coral reefs are the most threatened as they are in the periphery of coastline due to the impacts of human activities. Currently, there is limited knowledge on fringing shallow coral reefs along the south east coast of Queensland, particularly with the Burnett Mary Region. Our research team was contracted Central Queensland University (CQU) in Australia to develop a methodology to identify, map and analyse coastal benthic habitats including coral reefs using remotely sensed data and field data. The final outcome, a large scale quality map, shows the coastal benthic habitats in the Burnett Mary region showed the most dominant and least dominant classes and their coverage within each frame as well as the association between the spatial distribution of these classes and the physical environment (Fig. 3.25). Finally, a favorable evaluation of the outcomes based on available literate has been provided (Baban et al. 2008).

Furthermore, the issues of coastal management using remotely sensed data as well as assessing coastal vulnerability of the Northern Territory of Australia to climate change, using field work, aerial photographs and local knowledge, were explored and presented in national (Akumu et al. 2008) and international conferences (Pathirana and Baban 2008). Some of these research activities were funded by Darwin City Council and Southern Cross University in Australia.

3.7 Water Resource Science and Management: A Conclusion

Worldwide the demand for water consumption is increasing whilst the actual quantity and quality is decreasing. This dilemma makes obtaining agreements internationally, nationally and regionally, for managing and distributing this limited resource very complicated and potentially explosive. This is particularly detrimental to political and social stability in inherently geopolitically unstable regions such as the Middle East. The way forward is to train water managers and decision makers to effectively use new technologies, understand and appreciate holistic scientific concepts, to communicate effectively and to develop science based sustainable management options.

These issues are of a deep interest to Geo-scientists; in addition Geo-scientists can also foresee the trajectories and effects of increased human activities and climate change on water resources science and management and the subsequent issues of developing solutions to sustainably manage current and future challenges.

My research as part of available scientific literature shows that the majority of aforementioned issues can benefit from new technologies to develop proxy measurements, indicators and evidence for water quality parameters, water circulation, lakes management and water resources management. Geoinformatics can provide information on water resources management. In fact, the key to my achievements has been to be able to apply the principles of remote sensing and spatial information science to various water related issues with the view to problem solve and develop information for management and decision making.

My research in this field started with my Ph.D. at the School of Environmental Sciences at the University of East Anglia which offered me the exposure to scientists from a wide spectrum of disciples, I learned to value their conceptual approach to research and to appreciate their different professional viewpoints when dealing with a particular issue. I was fortunate to have had the opportunity to work on a wide range of issues related to water resource science and management including mapping, monitoring and modeling approaches using remotely sensed data and image processing techniques. This platform then was valuable with establishing a profile in the discipline through involvement in supervising student projects, obtaining research projects and conducting consultancy activities in the UK, Malaysia, the Caribbean and Australia.

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Chapter 4
Land Use/Cover, Agriculture and Biodiversity Research

4.1 Introduction

I started work in this field through a student project which required mapping agricultural land in the Warwickshire, UK based on old satellite images. This meant the lack of the necessary ground referenced data, then, I defined and promoted the use of 'representative' ground reference data with available historical records in the mapping process. My involvement in Jordan through other projects provided an opportunity, through a Ph.D. student project, to examine the changes in land use/cover over a period of 10 years due to agriculture. I was concerned with the loss of natural vegetation habitats in Tunisia and proposed a Geoinformatics based methodology to manage this issue; colleagues from the Tunisian Environment Agency were enthusiastic about this work. My major work was developed in Malaysia were in addition to mapping, I had to link the outcomes to development actions and also managed to develop and implement the 'Biophysical Land Unit' concept as the quantifiable spatial representations of the location, extent and dynamics of multiple ecological components (soil types, geology and topography (elevation, slope and aspect)) determining vegetation distribution. In the Caribbean, I noticed that vegetation habitat loss due to development was a major issue, hence, I developed, through several postgraduate projects, a Geoinformatics based approach to map land use/cover, define the BLU components for natural vegetation in Trinidad and Tobago and to develop ideas to manage forest fragmentation, conservation and reforestation issues. In Australia, I was involved with developing a methodology to monitor the variability of methane emission from the wetlands. I also researched the effects of anthropogenic factors such as urbanization and agricultural development on coastal wetlands in Australia using GIS.

Overall my research in mapping land use/cover, agriculture and Biodiversity have evolved as a response to my international activities, relocations and the need for developing geosciences based solutions in these locations. The sections below will provide details of the geo-based challenges when working in the areas of land use/cover, agriculture and Biodiversity.

S. M. J. Baban, *Managing Geo-Based Challenges*, Environmental Science and Engineering, DOI: 10.1007/978-3-319-07380-4_4,

4.2 Land Use/Cover, Agriculture and Biodiversity Research in the UK

In the 1990s, an issue which occupied many remote sensing data users, was the availability and use of ground referenced data for calibrating and validation outputs. Obtaining ground-referenced data involves collecting observations about the objects, areas or phenomena that are being sensed remotely. Derived information from this data will serve to link the context of the surface with the radiometric quantities of the remotely sensed data. Often this data is used as training sites for performing supervised classifications and to assess the accuracy of the classified image. In theory, the ground truth data should be collected simultaneously with the remotely sensed data. In practice, even under the best-case scenario, it is rarely possible to obtain instantaneous ground truth data for more than a small area or selected sample sites (Lo 1986; Mather 1991; Barrett and Curtis 1992).

I contributed by promoting and successfully demonstrating the use of 'representative' ground referenced data in supervised classifications. I argued that these data sets are collected under similar physical, environmental, climatological and atmospheric conditions to the remotely sensed data were developed and have been used successfully in supervised classifications (Baban 1993). However, in some cases no ground referenced data have been collected at all, making supervised classifications difficult (Girard and Isarwa 1990; Barrett and Curtis 1992). In another related research project, I intended to demonstrate the use of 'retrospective' ground referenced data in the classification process. Hence, I aimed to first develop a methodology to collect ground referenced data, in particular on agricultural land, compatible with satellite imageries, a number of years after the event. Secondly, use this data with corresponding satellite images to map land cover in Warwickshire with a special emphasis on farms. Finally, evaluate the accuracy of the classified image. A postal survey employing questionnaires was developed for collecting retrospective and compatible ground information with a Landsat TM imagery taken in June 1992. The questionnaires targeted selected farms in Warwickshire based on a composite image of the bands TM2, TM4 and TM5. The information was then used as 'training sites' in a supervised classification of the imagery as well as in the accuracy assessment of the classified image. The overall accuracy of the classified image was 87 %, individual class accuracy ranged from 80 % for Oilseed Rape and 94 % for water. The total area occupied by each class on the classified image was calculated. Comparisons with independent ground survey data indicated an acceptable degree of success. The methodology seems to be workable for obtaining and using compatible ground truth data with imageries taken in the recent past. The remote sensing community recognised the significance of this research and it was published in the *International Journal of Remote sensing* (Baban and Luke 2000) (Fig. 4.1).

I was also involved in identifying and mapping natural and semi natural habitat changes in Warwickshire using remote sensing and field based approaches. The aim was to develop strategies to minimise and manage the damage.

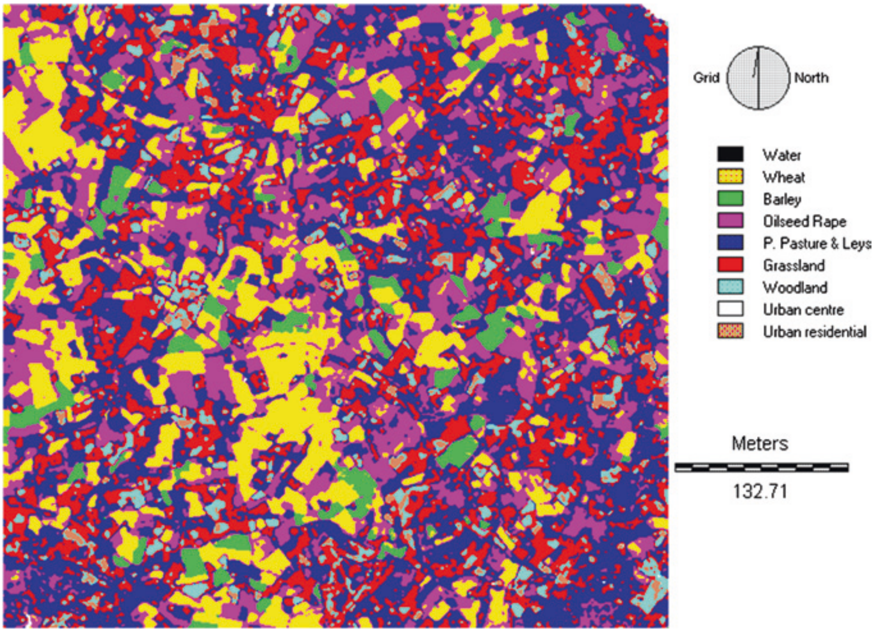

Fig. 4.1 Using representative ground truth data and remotely sensed data for mapping

The outcomes from this research which showed significant potential for using remote sensing in this field were presented in the *Remote sensing Society Students* meeting (Moran et al. 1996) and the *British Ecological Society Winter Meeting* (Moran et al. 1997) (Fig. 4.2).

4.3 Land Use/Cover, Agriculture and Biodiversity Research in the Middle East

4.3.1 Jordan

Further to my previous research in Jordan regarding water resource management as stated in Chapter 4, the Jordanian government has encouraged irrigated agriculture since the 1990s by providing low cost loans to drill private wells (Salamah et al. 1997; Kirk 1998). I was curious about the impacts of this practice on land use change. Hence, I set out, with the team, to examine the change in land use due to irrigated agriculture in north-eastern Jordan using Geoinformatics. Aerial photographs, SPOT and Landsat TM imageries were used, in a GIS environment, to map and examine changes in the farming patterns since 1990. Field surveys and questionnaires were used to ground truth the remotely sensed data. The results

Fig. 4.2 Warwickshire UK

indicate that the cultivated area has increased from just 28.5 ha in 1990 to over 1,000 ha in 2000 and that the number of farms has increased from 2 to 32 over the same time period. Furthermore, farm locations are moved annually, restricted by the position of the well and land availability. This also causes land use change. The outcomes were published in the *International Journal of Environmental Studies* (65) (Fig. 4.3a, b).

My research also examined the association between human settlement, irrigated agricultural activities, ground water use and sustainability within the Azraq basin in Jordan. The outcomes indicated that the ongoing agricultural activities and urban development can pose a serious threat to the quality and quantity of ground water which in turn can impact on the economical development if not managed urgently. Some suggestions to facilitate this objective were provided. This work was presented in the International Groundwater Conference, Groundwater India 88 which was held in the University of Rajasthan, Jaipur, Rajasthan in India (Baban 2008) (Fig. 4.4).

I was also involved in developing information regarding the physical settings in the Badia region in Jordan which included general geology, structural geology as

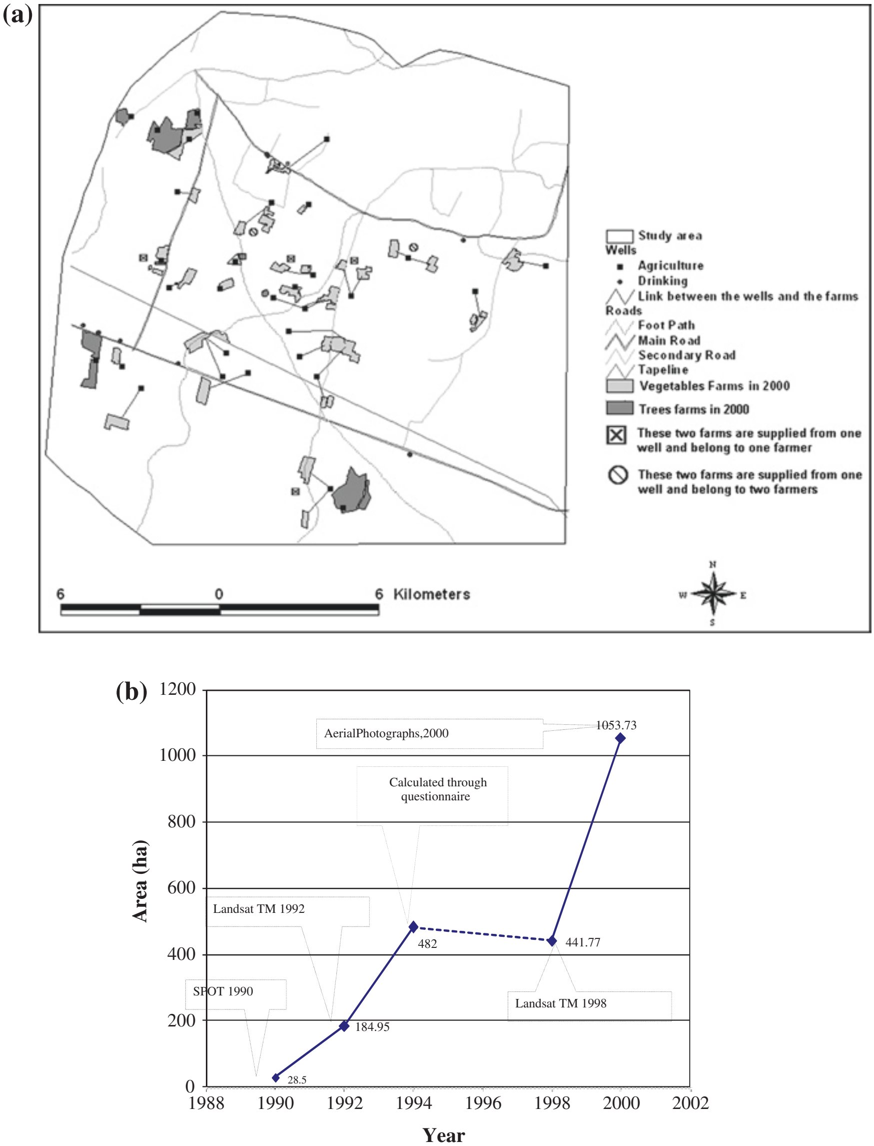

Fig. 4.3 **a** The agricultural activities in 2000 (after Al-Adamat et al. 2004). **b** Agricultural land change in the Badia Region Jordan between 1990 and 2000

well as topography and geomorphology. This work was published a chapter in a book dealing with managing water scarcity in the Badia Region of Jordan (Baban and Al-Ansari 2001) (Fig. 4.5).

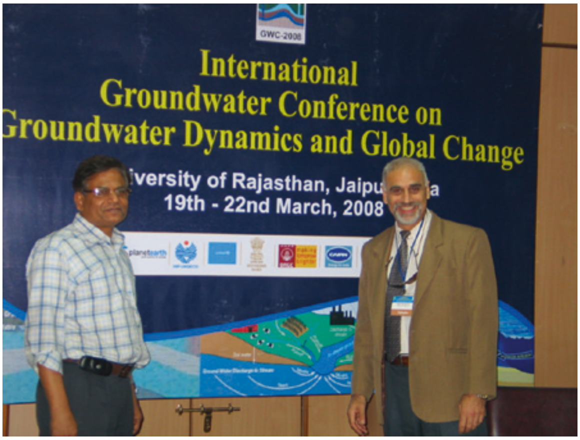

Fig. 4.4 Presented in the International Groundwater Conference, Groundwater India 88 which was held in the University of Rajasthan, Jaipur, Rajasthan in India

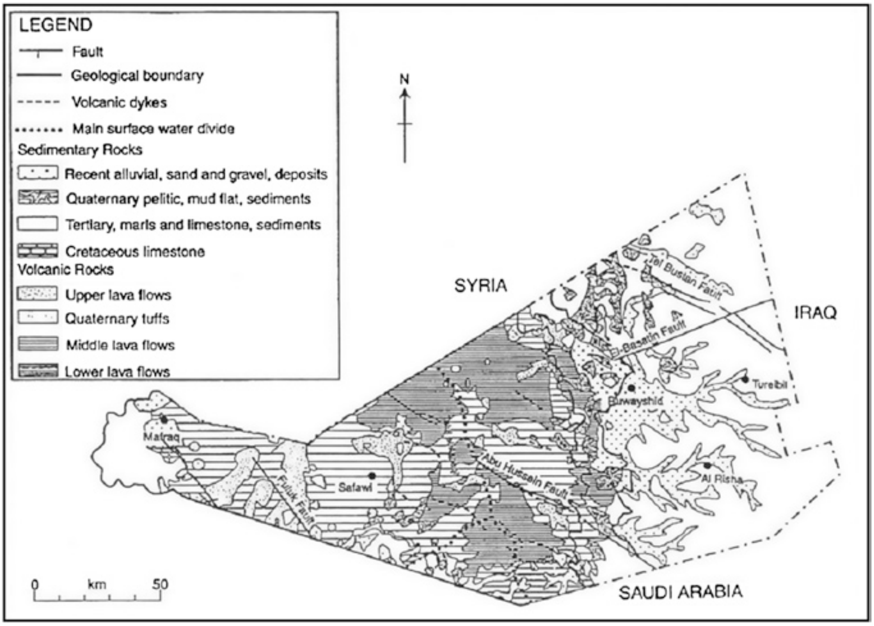

Fig. 4.5 Major geological divisions of the Northern Badia region (Baban and Al-Ansari 2001)

4.3.2 Tunisia

My involvement with Tunisia started in the 1990s through an overseas final year field course at Coventry University; I had the opportunity to visit Tunisia several times and to become familiar with its physical and geological settings as well as some of the ongoing geo-based environmental issues. One of these challenges was natural habitat loss. Tunisia contains some 2,200 different vegetation types, including 151 of the 870 endangered types existing in North Africa. In addition, Tunisia has 307 rare species, 16 of which are endemic to Tunisia, and 99 very rare species (MoELUP 1994; National Report 1995). There were no reliable information on the current state and the rate of change for these species. However, clearly the habitats of these and other natural vegetation communities are being damaged and destroyed at an ever increasing rate due to the impact of industrial and urban development, expansion of agriculture and managed forestry and neglect, adding to the burden of their existence in an arid climate. Under such climatic conditions, the necessary water and soil resources are fragile, which makes the survival of these habitats, and the conservation of biodiversity in Tunisia, a difficult task. These pressures are likely to be intensified in the future due to the effects of global climate change.

I noticed that some of the challenges were acknowledged by the Tunisian Government as they have signed up, and adhered to, a number of relevant international agreements, including The Berne Convention on the conservation of wildlife and natural environment in Europe, adhered to by the Tunisian Republic by law no. 95–75 of 7 August 1995. Furthermore a specific Tunisian concept was assembled by establishing the Tunisian National Agenda 21 during 1995 and through the formation of a section on the sustainable management of natural resources that focuses on management and use of water resources, land and biodiversity (National Report 1995).

My research argued that attempting to minimise the impact of these problems will need to rely on establishing a comprehensive inventory of the current habitat status as well as a clear understanding of the causes of natural habitat degradation. I examined the potential for adopting a comprehensive approach using ground referenced data, remotely sensed data and GIS to study, understand and to minimise the loss of natural vegetation habitats in Tunisia. A methodology for natural habitat management was developed and proposed using ground referenced data, remotely sensed data and GIS. This integrated approach will enable resource managers to devise effective habitat management strategies targeting the vegetation habitats most at risk currently and in the future by taking into account possible shifts in climate zones within Tunisia (Fig. 4.6). This research was presented in, and later published in the *Proceedings of the Satellite-Based Observation: A Tool for The Study of The Mediterranean Basin, International Conference* (Baban 1998).

4.3.3 Iraq

The Kurdistan region is highly suited for agriculture as it boasts large areas of arable land and fertile soil. The varied topography and associated rainfall regimes have created three basic micro-climatic zones; high rainfall (700–1,100 mm), medium

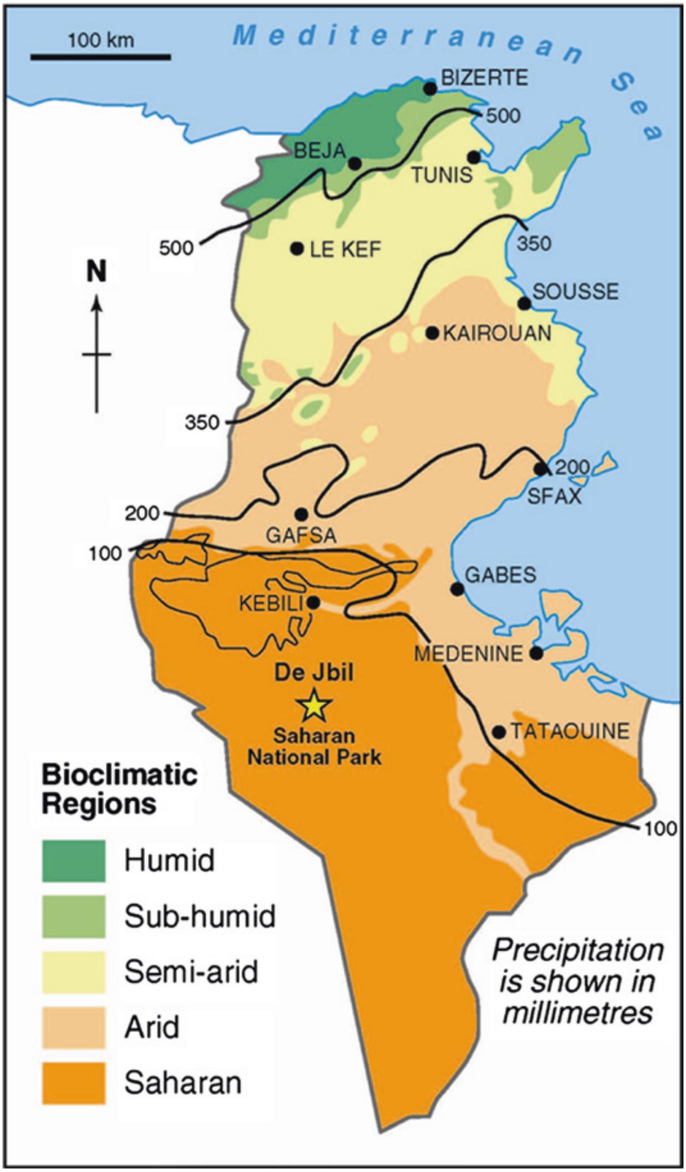

Fig. 4.6 Bioclimatic regions in Tunisia (Baban 1998)

rainfall (400–700 mm), and low rainfall (under 400 mm). In terms of produce; the high-rainfall zone contains mainly fruit orchards, wheat occupies most of the medium-rainfall zone, and barley is the main crop in the low-rainfall zone. Winter wheat and barley are planted in the fall (October–November) and harvested in the late spring (April–June) in accordance with the rainfall pattern (Mahdi 2000).

Records show that in the nineteen sixties Kurdistan used to provide central and southern Iraq with wheat, chick-peas, apples, peaches, grapes, and other products. Hence, the agricultural sector is a deeply rooted aspect of the society and economy in the Kurdistan Region (Baban 2012, 2013b, f). Unfortunately, agriculture and food production has declined significantly due to several factors that occurred in the period leading up to the Iraq War of 2003. These include; a 3-year drought that devastated agricultural production in much of the Middle East during 1999–2001; a growing dependence since early 1997 on the U.N. OFFP for basic foodstuffs which understated the need for local food production; central government's total focus on the military sector; failed policies, limited investment and deteriorating infrastructure; and serious land ownership and water rights issues (Mahdi 2000; Baban 2012, 2013a, b).

Evidently, agriculture in the Kurdistan Region is one of the most important sectors from a national food security perspective and it could become an important public revenue stabilizer at a time when oil revenue is highly volatile putting the government and its programs at risk. Additionally, the rehabilitation of this sector translates into reviving village life, creating more job opportunities, encouraging new industries, and upgrading our standard of living and people's quality of life (Baban 2013a, b, c). Clearly, this sector needs to be rebuilt and prioritized in terms of resources to sustainably develop agriculture to diversify the economy, as a strong KRG economy requires an efficient agricultural sector.

Once, I assumed by duties as the Minister of Agriculture and Water Resources, I was determined to make a significant part of my work in the Ministry concerted with developing and promoting the use of science in planning and managing strategic as well as daily problems. I focused my research on issues dealing with the challenges and opportunities surrounding the questions of food sufficiency and security in Kurdistan Region and produced a Road map charting the way forward (Baban 2012, p. 184, Baban 2013a).

4.3.4 What Is Needed?

In order to gather a comprehensive idea about Ministry in terms of functions, structure, the workforce and related issues and to develop science based options as the basis for sustainable planning, it was deemed necessary to established a clear understanding regarding the following two principles, which I consider to be critical;

i. Developing Evidence Based Understanding of the Issues at Various Geographical and Decision Making Levels Including

a. The Regional/National level

Agriculture was systematically devastated throughout the Anfal years, as 4,500.0 out of 5,000.0 villages were destroyed, internal conflicts, years of sanctions, the

UN oil for food program which ignored local food production and more recently by large quantities of relatively cheap food products from neighboring countries. Furthermore, the main cities in the region are located on the best available agricultural land, consequently, agriculture and food production has also been affected by the rapid urbanization in the region which is based on the current 'Master Plan' for cities. Furthermore, the region is currently experiencing an increase in water demand due to an expanding population, improvements in life quality and development activities (Baban 2013c).

In terms of functions, the Ministry has a wide band of responsibilities including; Agriculture and food production, Land management and allocations, Water Resources (Surface, Ground, Storage and Irrigation), Veterinary and meat production and Forestry. Whilst in terms of structure it has 13 General Directorates and some 17,000 employees and the current organization is the product of combining two of almost identical ministries, developed under two different administrations running Kurdistan Region and located in Suleimania and Erbil, without any structural adjustments or revisions. Given this background, the difficulty of delivering Ministry's plans and services effectively by its workforce is apparent due the challenges of establishing clear functions and line management duties amongst others

b. The International Level

All surrounding countries and nations are planning and building large numbers of irrigation projects and dams as well as inundating our markets with their agricultural products. Clearly, re-establishing agriculture is a challenge due to not being well established and consequently not being capable of competing on its merits and without a significant support and protection

c. Global Level

Based on the A1B Scenario of the IPCC, the region is likely to be greatly affected by climate change and will suffer from negative impacts on water resources, agriculture and food production due to changes in both rainfall and temperature (Lelieveld et al. 2012; Baban 2013d, e, f). Evidently, the Ministry needs to factor climate change impacts into its strategic plans and operations.

ii. Guiding Principles for Decision Making

Given the complexity of the issues, ongoing practices and the decision making and delivery mechanisms in the Ministry, it was necessary to collaboratively, involving the executives and decision makers in the Ministry, establish and to agree upon some simple principle guidelines for decision making and agree on a code of ethics and conduct. After extensive meetings we have agreement on the following guidelines;

i. The KRG is one Economic and Management Unit and we plan for full economic Integration and nation building.
ii. Make scientific and evidence based decisions, build effective and transparent systems, always follow process and ensure that Public interest and the law are supreme.

iii. Commitment to 'Collective and Representative Decision Making' through Activating the Ministry Advisory committee monthly meetings which consist of all relevant people, take the meetings to different parts of the Region.
iv. Commitment to 'Participatory Decision Making' through meeting our stakeholders during regional visits and meetings as well as establishing weekly Ministerial face to face meetings with citizens and relevant syndicates to facilitate their requirements and receive their suggestions for improving our services and performance.
v. Commitment to self evaluation and improvement, the Ministry will embark on continually reviewing its management and administrative system to serve the ultimate purpose, namely, improving quality and raising standards to achieve food and water sufficiency and security.

4.3.5 Planning for a Sustainable Future

Once this stage was reached we started to planning for a sustainable future and to 'define' the exact tasks and attempts to attach specific timelines to each process.

By this time, we understood that rehabilitating agriculture requires;

1. A clear and a practical vision, defining the priorities to fulfill the nation's agriculture and water needs.
2. An effective roadmap with clear objectives and timeframe developed based on consolations with all stakeholders.
3. Effective structure and modern management, training, and reflective systems for agriculture and sustainable water resources management.

The Ministry was tasked with achieving food and water sufficiency and security. Hence, our understanding of the task was delivering a healthy and nutritious diet, guided by the USDA approved standards (Table 4.1), to all citizens at affordable prices. It follows that this should be fulfilled by our local produce. In addition to sustainable development and serving all stakeholders in the best possible way.

Once the Road Map was developed based on an extensive consultative process which included extensive discussions and workshops in all the provinces as well as meetings with the University experts (Fig. 4.7). At the end of this process, the need for both short term and strategic priorities became clear and as follows;

4.3.5.1 Short term Planning and Management Issues

1. Preparing the Ministry and the its Workforce (fit for purpose through Higher degrees and training)) to deliver the Strategic Priorities.

    i. Revise Ministry's structure and enhance management services.
    ii. Simplify the hierarchy and decrease bureaucracy.
    iii. Provide direct, relevant and efficient services in all provinces.

Table 4.1 The list of individual needs of food according to global standards

	Type of food	Units	Current capacity 2008	Our plan for 2013	USDA standard
1	Wheat	Kg/year	68	100	73.7
2	Chicken	Kg/year	5.9	19.6	65
3	Red meat	Kg/year	22.7	40	
4	Fish	Kg/year	0.15	1.3	
5	Lentils and chick-peas	Kg/year	7	12	
6	Vegetables	Kg/year	54.6	132	106
7	Fruits	Kg/year	12.5	50	65
8	Eggs	Eggs/year	75	129	180
9	Oil	Liter/year	–	15	WFP 15.4
10	Milk	Liter/year	45	80	176
11	Honey	Kg/year	0.14	0.24	–

Fig. 4.7 Developing the Ministry Road map based on extensive meetings, workshops and consultations with University experts

Table 4.2 A Sample of Ministry requirement for Higher Certification

Number	Experts	High diploma	Master	doctorate
1	Plant protection/fungus disease	–	3	
2	Plant protection/harmful fruits		3	
3	Plant protection/gainful fruits		2	
4	Plant protection/genetic and Breeding		2	
5	Open cultivation (for vegetable)		4	1
6	Managing and developing horticulture nursery		4	2
7	Effect of purring on fruit production			
8	Organic cultivation		6	2
9	Cultivation by hydroponic method		3	1
10	Effect of weather on the forest environment		4	2
11	Tissue culture and threat of damage		2	1
14	Reformation of hereditary of forest tree		2	
15	Soil erosion (events, causes, treatment)		3	
16	Classification of rangeland plant		2	
17	Managing desertification		3	
18	Plant protection/forest diseases		2	
19	Plant Protection/IPM		8	2

Achievements in this context includes some changes to Ministry's structure (matching Form with Function) and management practices; measuring success based on productivity; developed a list of the Ministry's needs in Higher Education and training (Table 4.2); project proposal and evaluation process; delegation of authority to provinces; revised training needs; job descriptions and performance evaluation based on merits.

2. Granting more support to productive farmers and link support to actual productivity in terms of quality and quantity. Achievements include defining the Productive Farmer, reviewed forms of support and linked to productivity;
3. Providing timely and effective services. Achievements include developing the Agricultural Calendar for KRG (Fig. 4.8); target support to productive farmers (Fig. 4.9), Plan to use Agro- climatic Zones …
4. Improve the quality assurance and control and reporting on technical, financial and management issues. Achievements to date include activating the Following Up section; Upgrading and Expanding Vet Labs, Planning for VET SOS and portable test kits.
5. Improve the quality assurance and control and reporting on technical, financial and management issues. Achievements include activating the Following Up section; Upgrading and Expanding Vet Labs, Planning for VET SOS and portable test kits.
6. Enhance communication with stake holders. Achievements include effective Website, weekly meetings with citizens; regular site visits; regular meetings with various syndicates; complaint and suggestion box; Taking Ministry Advisory Committee to Garmean, Sulimaniya, Duhock and Aqra.

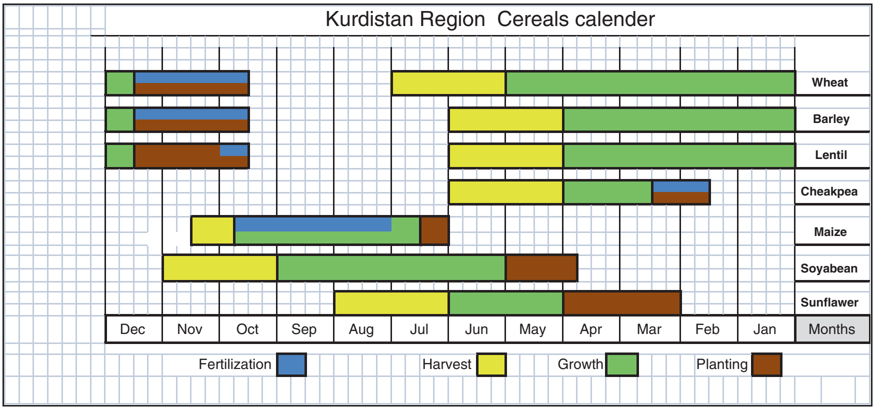

Fig. 4.8 Developed Agricultural Calendar showing Cereal production in the region (Baban 2013a–g)

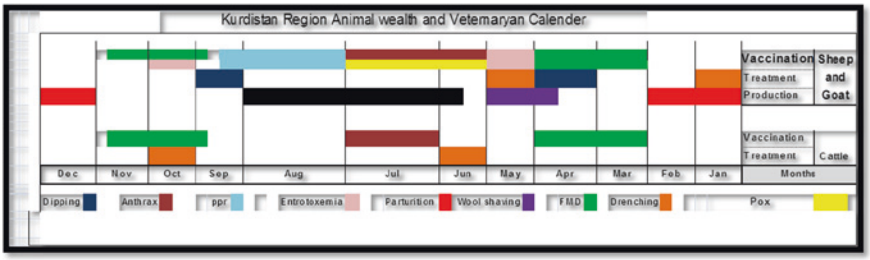

Fig. 4.9 Developed Calendar for supporting animal wealth showing the timelines for various services and activities in the region

7. Protection of human rights and achieving equity amongst Ministry staff. Achievements include developing a health and safety section and program, reforming the process of staff appointment by improving transparency and fair competition by appointing through CV's and interviews and finally focusing on gender equality and promoting the role of women and youth.

4.3.5.2 Strategic Planning and Management Issues

The planning was conducted based on analyzing all available data regarding agricultural produce, poultry, livestock, fish, forests, meadows, and honey. The data was colour coded as Green: KRG Production achieved self-sufficiency (100 % of what is needed); Orange: KRG Production achieved 50 % or more of the required

	Produce	The Region's need/ tonnes	Produce of 2011		Objective for 2013		Projects to achieve the objectives
			tonnes	percentage	percentage	tonnes	
1	Wheat	500000	500000	100%	600000	120%	1- Provide trusted seeds
2	Oat	600000	70000	11%	150000	25%	2- Provide irrigation machinery
3	Corn	240000	20000	8%	30000	12,5%	3- Pest control
4	Sun flower	37500	10500	28%	15000	40%	4- Provide water sources during drought

Fig. 4.10 Developed datasets for the Road Map

self-sufficiency and Red: KRG Production has achieved less than 50 % of the required self- sufficiency (Fig. 4.10) (Baban 2013a). The analysis indicated the need for;

1. Achieving food self-sufficiency and security Achievements include protecting, promoting and marketing local agricultural products (Farm to Folk) as well as developing a list for managing imports and protecting local produce.
2. A holistic approach for managing all sectors in agriculture including forestry, horticulture, plant and animal production, poultry projects, animal husbandry, irrigation projects, and research and development. Achievements include KRG is one economic and Management unit, Planning to use Agro climatic Zoning for food production.
3. Provision of a basket of help to farmers and link to productivity.
   Achieved to date: improved seeds, fertilizers, farm equipment, transport subsidy, machinery, agricultural extension service, feed for their animals, training in modern agricultural methods and techniques as well as health and safety issues). All of these are linked to Productive farmers and Productivity.
4. Support agricultural applied research to deal with issues of increasing production, disease control, modern irrigation, water harvesting methods and related climate change issues. Defining the role of Research, Training and Extension. Achievements include revising the role of the Research, training and Extension GD.; developing links with Universities and research institutions.
5. Finalize Agriculture Act's rules and regulations. Achievements include successfully completing the Forestry law was completed and submitting the water management and protect law. In addition to proposing legislations for protecting natural meadows, livestock and wildlife as well as legislation to control import of livestock and poultry.

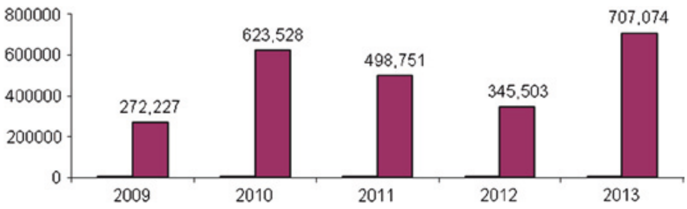

Fig. 4.11 The production of wheat in the region since 2009 and shows that production has reached 707,074 tons during 2013

6. Provide sustainable sources of water through increasing storage capacity, water harvesting and effective irrigation methods. Achievements include currently building a number of dams, ponds and irrigation projects.
7. Encourage and promote the private sector. Achievements include the London Conference and a possible conference in Holland.
8. Managing agricultural land issues. Achievements include managing both;

- Unauthorised development issues, completed a comprehensive survey and suggested legal and practical solutions to the Council of Ministers.
- Land Ownership issues, organising a mini Conference, Proposal for Council of Ministers and invitations for international companies/Universities to provide the mapping, classification and geo-referencing aspects.

4.3.6 Tangible Outcomes from the Road map

4.3.6.1 Conceptual

The Ministry is currently operating and functioning based on evidence based planning, employing Scientific concepts, developing and using Scientific basis for decision making, developing the work force, developing systems and regulations to ensure human and public rights as well as health and safety issues.

4.3.6.2 Tangible

Based on available date, the Ministry has reached self sufficiency for the strategic Produce of Wheat (Fig. 4.11) (Baban 2013e, f). Figure 4.11 is an illustration of the production of wheat in the region since 2009 and shows that production has reached 707,075.0 tones, given what is required is about 500,000.0. The same is true for Potatoes as shown in Fig. 4.12 which demonstrates that the production of potatoes at 2013 was more that 87,000,0 tones.

Furthermore a comparison between the levels of production, required for self sufficiency in the Region, and the actual levels of production for a number of

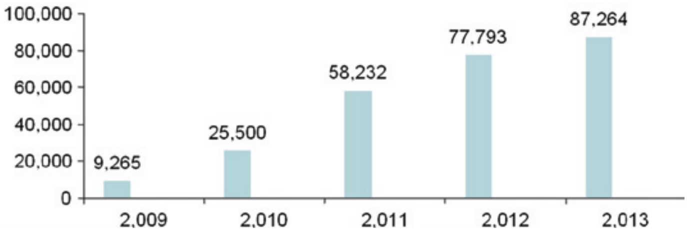

Fig. 4.12 The production of potatoes since 2009 and shows that at 2013, the production was more that 87,000,0 tons

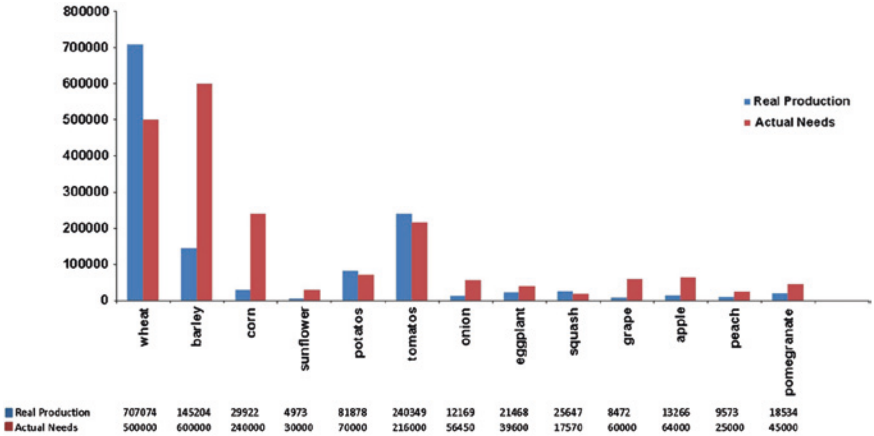

Fig. 4.13 A comparison between the levels of production, required for self sufficiency in the Region, and the actual levels of production for a number of strategic produce

strategic produce will show, the region has realized self sufficiency in Wheat, potatoes and tomatoes (Fig. 4.13) (Baban 2013e, f).

The analysis for the geographic distribution for strategic produce throughout the region (Fig. 4.14) (Baban 2013f) will show that some regions such as Duhock are showing a high level of productivity whist Garmen's production is generally low. This information has motivated the Ministry to consider Agro climatic zoning as an integral part of the ministry's future planning. Agro-climatic zoning refers to the division of an area of land into land resource mapping units, having unique combination of landform, soil and climatic characteristics and or land cover having a specific range of potentials and constraints for land use. This approach to agriculture focuses attention on the soils, rainfall and temperature requirements of crop and on the management systems under which the crops are grown based on output maps showing agro-climatic zones and land suitability. Hence, it is one of the most important bases for agricultural developmental planning as agriculture in a given region heavily relies on careful assessment of agro-climatic resources. Having examined the statistics and the geography of food production in the region

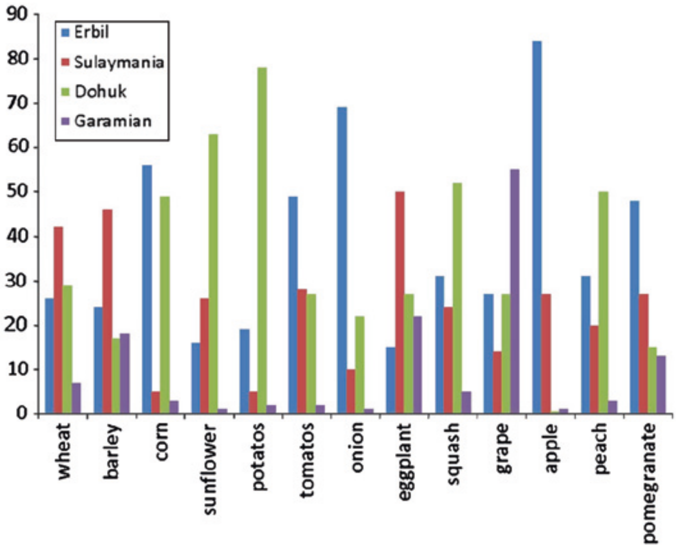

Fig. 4.14 The geographic distribution for strategic produce. Clearly, some regions such as Duhock are showing a high level of productivity whist Garmen's production is generally low

for 2011 and 2012, the need for developing agro-climatic zones and using them as the basis for food production became a priority for the Ministry. Hence, I am currently, leading a team developing agro-climatic zones for all the strategic products in the region using available data and employing GIS based analysis to define and combine the most suitable physical and environmental conditions for the evolution of each product (Fig. 4.15).

4.3.7 Research Needs

The experiences indicate that given the current status of agriculture, the workforce composition and training level as well as future needs, the Ministry needs Applied Internationally approved research dealing directly with and solving current and future challenges in Agriculture and Water Resources (Baban 2013e, f). Examples include:

1. Managing Climate Change Impacts (next generation of crops that are resistant to heat/humidity; managing potential diseases, ways of increasing productivity).
2. Using Geoinformatics (GIS and Remote Sensing) for developing sustainable management and development scenarios.
3. Focusing on Holistic management and sustainable development principles for managing water resources.

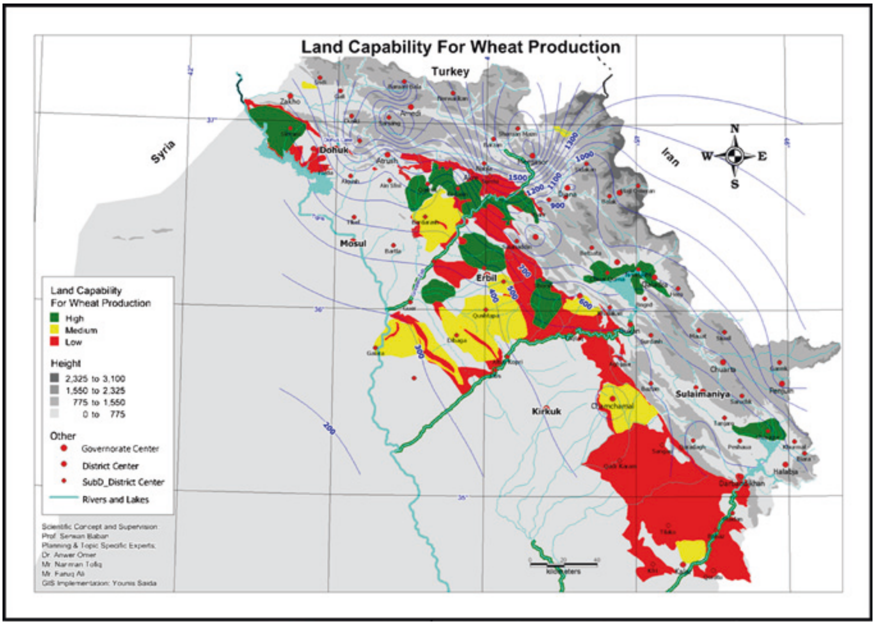

Fig. 4.15 Agro Climatic Map of Wheat production

4. Prediction and modeling weather and climate data.
5 Using modern principles technologies for water preservation and harvesting, protecting hydrological catchments; protecting from erosion and promoting carrying capacity principles to minimize floods and landslides.

On reflection, I note the difficult task given to the Ministry, and the small budget by which to achieve it. However, applying scientific principles and observing participatory decision making principles, a Roadmap was developed during June 2012 aimed to achieve food sufficiency and security for the region. The road map provided a way forward to rehabilitate and improve the agriculture sector based on a vision that introduces effective modern production, training, management and reflective systems for sustainable agriculture and food production in the region. The evaluation of the implementation of the road map shows an optimistic picture as self sufficiency has been achieved with some key agricultural strategic produce such as Wheat and Potatoes and the work started on some large dames as well completing the work on some 86 ponds and have plans for build some 50 more. The outcomes also show the difficulty of the task and the importance of implementing the plans based on a clear and a transparent process and to give the highest priorities to quality assurance and control processes. Finally, collective and participatory decision making is an effective way ahead. These efforts were presented in and international workshop in London, UK (Baban 2012). Later through a reflective process the implementation of the Road map over the period of 12 months and linking Ministry work and thinking to regional and international cooperation platforms. These efforts were presented in and international conference in Sweden (Baban 2013e) and in another international conference dealing with promoting regional and international cooperation (Baban 2013f). Currently, the Ministry is focused on developing a 5 year strategic plan for the Ministry (Baban 2013b, d).

4.4 Land Use/Cover, Agriculture and Biodiversity Research in Malaysia

The economical prosperity over the past three decades in Malaysia has generated a significant demand for all forms of recreational activities (Draper 1994). This background, and the declaration of the Langkawi Island as a duty free port in 1987, made the island the focus for recreation activities in Malaysia. Langkawi Island is currently amongst the most popular tourist destinations; the rate of tourist increase from 1988 to 1989 was about 31 % (Jusoff and Hassan 1996). Subsequently, the island has been undergoing rapid development in terms of expanding road networks and the construction of hotels and holiday complexes (Fig. 4.16). In this research the land use/cover distributions in the Langkawi Island, Malaysia were mapped based on field work (Fig. 4.17) as well as using remote sensing and GIS. A Landsat TM satellite image taken in March 1995 was processed, geo-corrected and analysed. An unsupervised classification was performed based on spectral data from a composite image of the bands TM3, TM4 and TM5. Using this output, field data together with available secondary data consisting of topography, land use and soil maps were used to perform a Maximum Likelihood supervised classification. The overall accuracy of the output image was 90 % and individual class accuracy ranged from 74 % for rubber to 100 % for paddy fields. The classified areas on the image were mainly confined to the mountainous and hilly regions on the Island. A shaded relief map, simulating sunshine conditions, showed that the unclassified areas are located in the shadowed slopes which are slopes facing the west. Consequently, the imagery was subdivided on the basis of slope aspect and a stratified classification was performed. As a result, the overall accuracy increased to 92 % and the individual class accuracy for the inland forest class increased by 9 to 90 % (Fig. 4.18). Using IDRISI, individual class areas as well as percentages were calculated. The kappa coefficient for the classified image was 0.90. This research was published as a paper in the *International J. Remote sensing* (Baban and Wan-Yusof 2001a).

Qualitative analysis indicated that topography is the main control on the spatial distribution of land use/cover types on the Island. As Langkawi Island has been undergoing rapid development in the last decade, successful planning will require reliable information about land use/cover distribution and change. This study illustrated that remote sensing and GIS are capable of providing such information. This research was published as a conference paper in the *proceedings of the 20th Asian*

Fig. 4.16 The Impact of rapid development on Langhkawi Island, 1997

Fig. 4.17 Fieldwork in Malaysia, 1997

Conference in Remote Sensing (Wan-Yusof and Baban 1999) and later in a more substantial form in the *Hydrology Science Journal* (Baban and Wan-Yusof 2001b).

The connection between land use/cover distribution in a region and the combined effect of physical characteristics such as the climate, soil and geological substrate

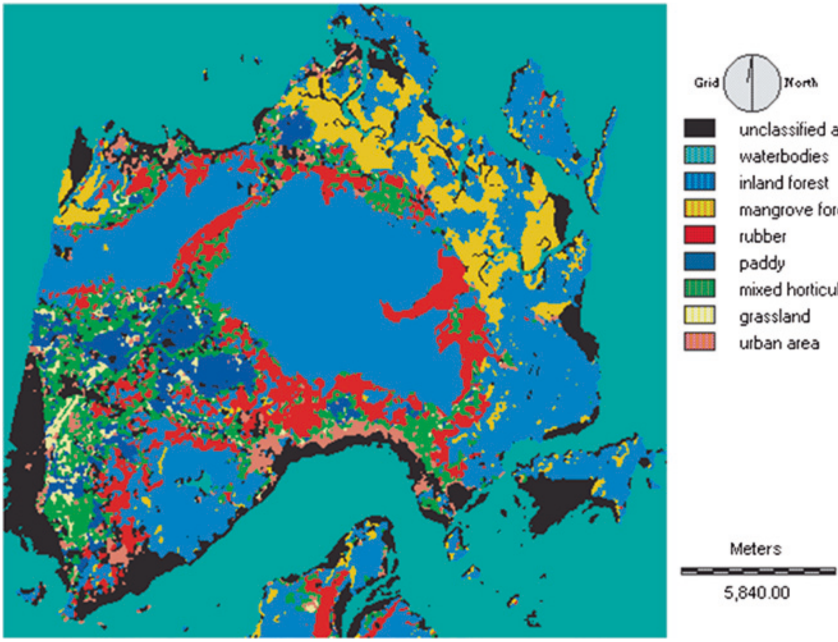

Fig. 4.18 Land use/cover mal of Langkawi island based on Satellite images (Baban and Wan-Yusof 2001a, b)

has been recognised for some time. It is also apparent that climate can determine the nature of both soil and vegetation and furthermore, climate change can induce changes in eco-climatic habitats within mountainous environments. (Brooks 1972; Walter 1973; Wadsworth and Treweek 1999). I was interested in exploring the association between terrain attributes (elevation, slope, etc.) and vegetation parameters that control spectral response (flora, density, stratification, etc.) through the concept of Biophysical Land Units (BLU) as the quantifiable spatial representations of the location, extent and dynamics of multiple ecological components determining vegetation distribution. These components are the pieces of an ecosystem or ecotype and may include soil types, geology and topography (elevation, slope and aspect). Hence, I aimed at developing a methodology to identify and extract biophysical land units (BLU) for tropical mountainous environments, the Langkawi Island, based on the physical factors determining the ecological optimum using remotely sensed data and GIS. Furthermore, I intended to evaluate the BLU's and the methodology using field-based data supplemented by available secondary data sets. In tropical environments, this type of study is likely to have complications. This is mainly due to difficulties in identifying the species involved on the ground due to access limitation for field observations, height of trees and their distribution in inaccessible terrain. Furthermore, vegetation communities tend to have shallow-roots and produce and shed flowers/fruits at irregular periods. An added difficulty is the presence of multilevel canopies

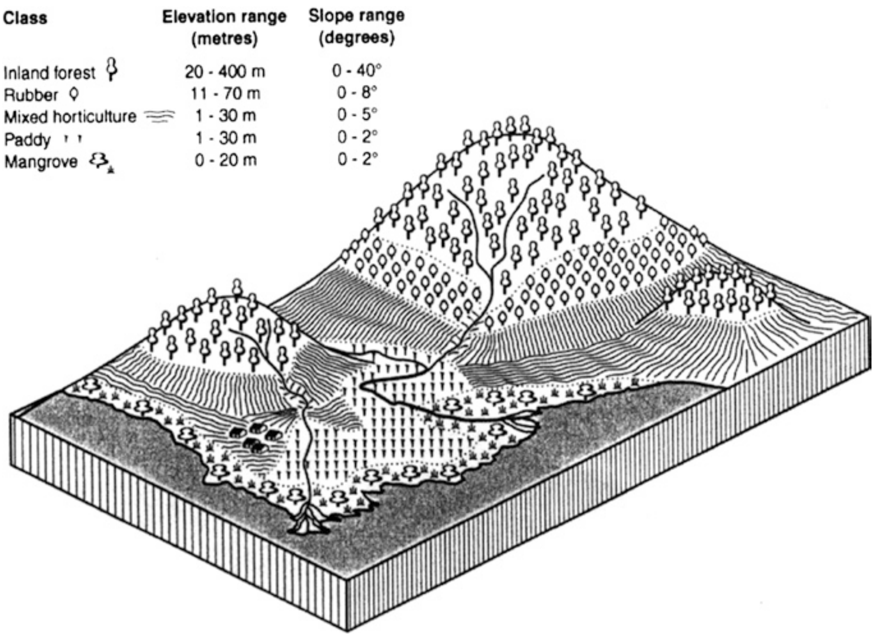

Fig. 4.19 Schematic representation of land use/cover types on Langkawi Island based on the defined BLUs (Baban and Wan-Yusof 2001a, b)

and numerous communities co-existing in this complex environment. In fact, a larger number of vegetation communities can be found in a few hectares of the Amazon rain forest as opposed to all the identified ones in the cold and temperate forests.

In this research, a methodology to define biophysical land units (BLU) influencing land use/cover distribution on Langkawi, Malaysia was developed by taking into consideration the following factors; elevation, slope, soil type and geology (Fig. 4.19) (Table 4.3). Neither temperature nor rainfall had significant variation within the Island and were therefore not considered for inclusion in the BLU's. IDRISI, a raster based GIS, was utilised to establish spatial associations between the land use/cover types, derived from remotely sensed data, and the aforementioned physical factors on the island. The established BLU's appear capable of defining the ecological optimum and consequently the spatial domain of land use/cover types on the island. Indeed, when validated against field based data, supplemented by available secondary data sets, the results explained between 92 and 96 % of land use/cover distribution. Overall, topography seems to be the principal physical factor in defining BLU's and is in accordance with similar research in tropical mountainous environments. This type of deductive geo-ecological research is essential in order to increase our understanding of land use/cover distribution and to deduce the required BLU's for their preservation. In addition such analysis allows the formulation and implementation of environmental plans for, e.g., identifying suitable locations for reintroducing or introducing specific land

Table 4.3 Correspondence between defined BLU's for land use/cover types with field based data and available secondary data sets (Baban and Wan-Yusof 2001a, b)

Location				The Correspondence				
no	x	y	Site	Land Use/ Cover	Elevation (metres)	Slope (degrees)	Soils	Geology
1	204 330	714 000	Tanjung Rhu	mangrove forest	0-20 ✓	0-2 ✓	sandy loam to clay loam ✗	alluvium ✓
2	209 000	698 000	Bringin Hill	inland forest	80-100 ✓	> 20 ✓	sandy loam to clay loam ✓	limestone & minor sandstone and Shale ✓
3	206 220	710 340	Kampung Batu Gajah	m. horticulture	0-20 ✓	0-2 ✓	fine sandy clay ✓	alluvium ✓
4	203 150	711 580	Padang Lalang	paddy	0-20 ✓	0-2 ✓	coarse sandy clay ✓	alluvium ✓
5	204 000	206 700	Gunung Raya	inland forest	380-400✓	>20 ✓	sandy loam to clay loam ✓	granite ✓
6	208 000	709 650	Kilim	inland forest	0-20 ✗	0-2 ✓	silty clay ✗	alluvium ✗
7	201 360	704 850	Ulu Melaka	inland forest	20-40 ✓	>20 ✓	sandy loam to clay loam ✓	sandy loam to clay loam ✓
8	204 150	701 600	Kampung Kelibang	Rubber	0-20 ✓	6-12 ✓	fine sandy clay ✓	mudstone, ✓ shale & sandstone
9	203 500	702 600	Batu Asah	Rubber	40-60 ✓	12-20 ✗	clay to silty clay ✓	mudstone, ✓ shale & sandstone
10	205 190	702 250	Kelibang	Rubber	20-40 ✓	6-12 ✓	clay to silty clay ✓	mudstone, ✓ shale & sandstone
11	202 500	700 500	Bukit Tekoh	rubber	20-40 ✓	2-6 ✓	fine sandy clay ✓	mudstone, ✓ shale & sandstone
12	203 000	206 000	Ulu Melaka	inland forest	220-240✓	>20 ✓	sandy loam to clay loam ✓	granite ✓
13	200 000	704 700	Ploy Gaong	paddy	0-20 ✓	0-2 ✓	coarse sandy clay ✓	alluvium ✓
14	201 600	700 500	Bukit Malut	m. horticulture	0-20 ✓	2-6 ✓	Clay to fine Sand Clay ✓	mudstone, ✓ shale & sandstone
15	199 500	695 990	Bukit Malut	inland forest	20-40 ✓	>20 ✓	sandy loam to clay loam ✓	mudstone, ✓ shale & sandstone
16	196 740	696 340	Bukit Wang	inland forest	0-20 ✓	0-2 ✓	fine sandy clay ✓	mudstone, ✓ shale & sandstone
17	194 700	704 200	Kg. Bohor	paddy	0-20 ✓	0-2 ✓	coarse sandy clay ✓	alluvium ✓
18	200 190	707 140	Gunung Raya	rubber	0-20 ✓	6-12 ✗	coarse sandy clay ✓	granite ✓
19	200 700	708 250	Padang Gaong	rubber	40-60 ✓	6-12 ✓	coarse sandy clay ✓	granite ✓
20	202 800	711 150	Kampung Huma	m. horticulture	0-20 ✓	2-6 ✓	coarse sandy clay ✓	mudstone, ✓ shale & sandstone
21	198 350	701 240	Kampung Bayas	m. horticulture	0-20 ✓	2-6 ✓	coarse sandy clay ✓	alluvium ✓
22	195 700	708 550	Kg. Lelubi	mangrove	0-20 ✓	0-2 ✓	silty clay ✓	alluvium ✓
23	204 000	711500	Bohor Merah	mangrove	0-20 ✓	0-2 ✓	silty clay ✓	alluvium ✓
24	199 860	700 360	Kampung Bayas	m. horticulture	0-20 ✓	2-6 ✓	clay ✓	mudstone, ✓ shale & sandstone

use/cover types to specific locations on the island. This research was published in the *Asian Journal of Geoinformatics* (Baban and Wan-Yusof 2002). During this period our team has formed a strong association with Malaysia colleagues working in the Universities as well as the Remote sensing Centre (Fig. 4.20). These associations proven to be useful to facilitate the fieldwork, introduce local knowledge and to verify the outcomes from the research.

Fig. 4.20 Visits to University Sains Malaysia (USM) and Malaysian Centre for Remote Sensing during 1997

4.5 Land Use/Cover, Agriculture and Biodiversity Research in the Caribbean

Upon my arrival, I noticed that natural vegetation habitats in the Caribbean region are increasingly threatened by development in terms of urbanisation, industrialization and tourism activities (CARICOM/TFAP 1993; Adames 2001). These are likely to be joined in the future by the effects of global climate change. However, the need to preserve vegetation biodiversity is an uphill task as it will require establishing a geographically referenced inventory for the current habitat status, monitoring and assessing the impact of these activities, predicting future conditions and arriving at a better understanding of the processes supporting and harming vegetation habitats. I started to develop a methodology for natural habitat management, using Trinidad and Tobago as a case study, is proposed and presented using ground-referenced data, remotely sensed data and GIS. This integrated approach will enable resource managers to devise effective habitat management strategies targeting the vegetation habitats most at risk currently and in the future by taking into account possible shifts in climate zones. This research was presented at and published in the proceedings of the *Urban and Regional Information Systems Association (URISA) 2001 Caribbean GIS Conference* (40) and later in a comprehensive form in the *Tropical Biodiversity Journal* (57).

Countries in the Caribbean region face unique development challenges arising from their small size and vulnerability to natural disasters as well as the resulting economic volatility (Varnes 1984; Crozier 1986). However, it should be mentioned that in this region there is a severe deficiency in accurate and up to date information on land resources despite the ongoing rapid rate of urbanization, population growth and the substantial expansion in industrial and agricultural development. Hence, I, with assistance from a team, developed an up to date Land use/cover map of Tobago (Fig. 4.21) and to conduct a quantitative change analysis over the last 45 years using remotely sensed data and GIS. This research has used three

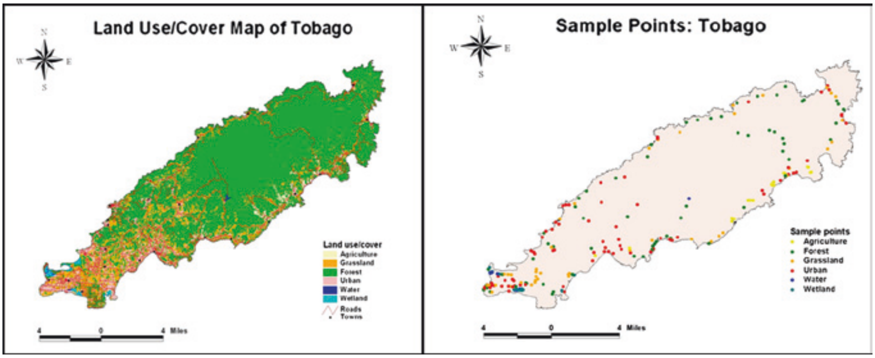

Fig. 4.21 Land use/cover map of Tobago, 2011 (Baban et al. 2009)

Landsat Enhanced Thematic Mapper (ETM+) satellite images (2001, 2002 and 2003) for developing a land use/cover map of the island of Tobago to begin to fill this void. The images were corrected for geometric, atmospheric, cloud and cloud shadow and topographic effects. A supervised classification approach that employed a maximum likelihood classifier was applied. The overall accuracy of the output image was 94.7 % and accuracies for the individual classes ranged from 85.7 % for bamboo to 100 % for urban. The kappa coefficient for the classified image was 0.93. Furthermore, a quantitative change detection analysis was performed, utilizing the classification output and a vectorised 1956 land use map of the island. The outcomes revealed a significant increase in urban sprawl contrasted by a significant decrease in agricultural land use over the 45 year period. The analysis indicated that this trend has emerged due to a direct exchange of agriculture for urban development. This research was presented at a *Conference organized jointly by the University of the West Indies and Tobago House of Assembly* during 2004 (Baban 2004) and was later published in an extensive form in the *Caribbean J. of Earth Sciences* (Baban et al. 2009).

The Caribbean Islands, due to their geographical location and geological history contain some 13,000 species of vascular plants (Adames 2001). Their rich biodiversity is under serious threat, however the extent of the problem is not known since the loss cannot be quantified by deforestation and conversion rates, there are also other social, economic, and ecological values to consider. In order to deal with this issue, I have built on my research in Malaysia which focused on developing Biophysical Land Units (BLUs) as a quantifiable spatial representation of the location, extent and dynamics of multiple ecological components determining vegetation distribution. The Units are a culmination of the pieces of an ecosystem or ecotype and may include soil types, geology and topography (elevation, slope and aspect) (Baban and Wan-Yusof 2002). In the Caribbean, I developed and defined BLUs based on extraction, processing and manipulating data on land use/cover, geology, soil, rainfall, aspect, elevation and slope. Furthermore, weights were derived for each component of the BLUs based on the results of the ecological

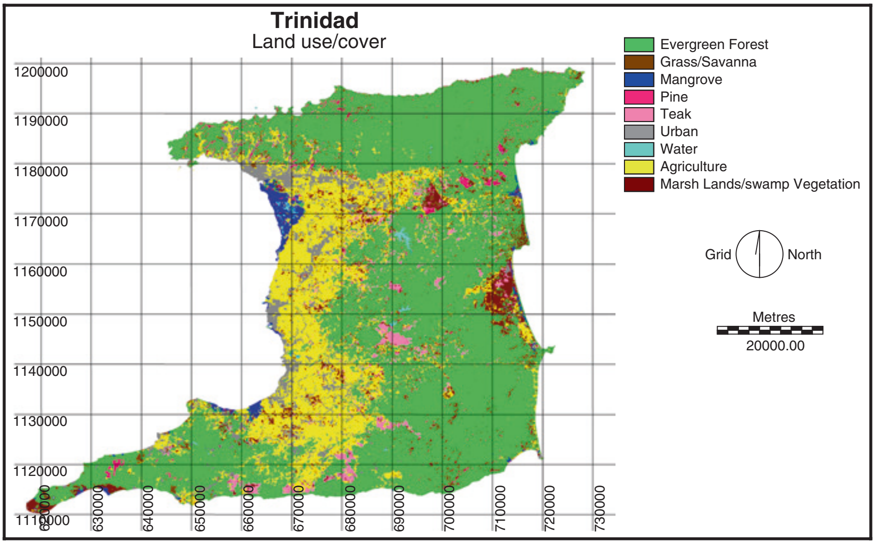

Fig. 4.22 Land use/cover map of Trinidad (Chinchamee et al. 2006)

combination and criteria developed. The outcomes indicated that elevation was the most influential, since all the land use/cover classes are dependent on elevation, rainfall and slope. Based on the results generated from this research the associations with the land use/cover types and the physical characteristics which drive them are now known. BLUs can be used effectively for different applications related to the optimal choice of land use/cover for an area. For example, in the case of reforestation, only the land cover types which are suited for a particular environment should be used in that process based on their BLUs. This is to say, the BLUs would assist in determining which natural plant communities would be most suitable for a particular area identified for reforestation. On the other hand, areas can be identified for reforestation based upon the forest communities that are under threat and the location of their BLUs. Once natural plant habitats have been considered to be under serious threat, the location of the reforestation process could now be determined based upon what the desired BLUs for those plant communities are, then they can be re-introduced successfully to the suitable environments (Fig. 4.22).

In the planning process this information can assist policy makers in determining the most suitable location for industry; suggesting that industries be located on lands where the biophysical properties may not be crucial for natural plant communities. There may also be situations where "prime forest lands" must be allocated to industries based on other consideration such as infrastructure, location of other industries, or access to ports or harbours. The developed BLUs can also assist in locating alternative sites where these plant communities could exist. Clearly, the management process of the natural plant habitats can be enhanced by this additional information, where decision makers cannot only now decide upon the most appropriate locations for industries, agriculture, and housing but also

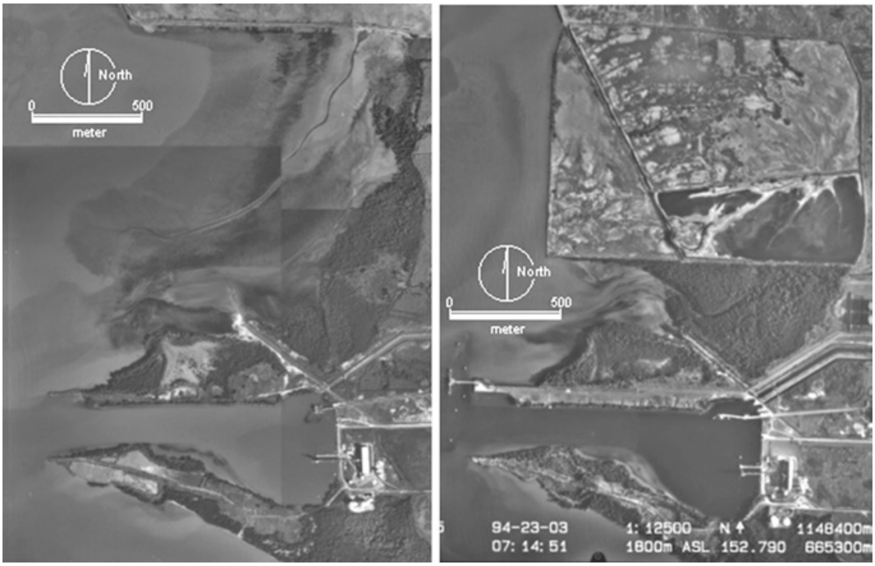

Fig. 4.23 Lisas Bay as portrayed in the mosaicked aerial photos of 1980 and 1994 (Al-Tahir and Baban 2005)

areas for forest reserves and reforestation. Additionally, the most suitable plant communities can be used based on the biophysical properties of locations identified for the reforestation efforts. Some aspects of this research was presented and published in the *Proceedings of RSPSoc 2006: Understanding a Changing World* (Chinchamee et al. 2006), an extended version with additional analysis was presented and published in the proceedings of the *Twenty-eighth Annual ESRI International User Conference* during 2008 (Chinchamee et al. 2008).

Our research team also became interested in investigating the spatial and temporal changes in mangrove in the area of Lisas bay in Trinidad using aerial photographs. The mosaicked aerial photos of 1980 and 1994 of the area showed complicated changes in land cover/use types. For example, about 35 % of the mangrove area (~27 ha) was cleared for industrial establishments in two different sectors. However, new mangrove grew into the bay gaining about 14 hectares in a region neighboring the outflow pipe of the nitrogen factory. Furthermore, some 106 ha of new land were reclaimed from the sea in one large tract. This research was published in the *journal of Tropical Biodiversity* (Al-Tahir and Baban 2005) (Fig. 4.23) (Table 4.4).

I also became involved with Dr. Graeme S. Cumming of University of Florida, Gainesville, USA and we collectively developed a collaborative project entitled ‘Sustainability and Land Use in the Caribbean Region’. The project focused in examining the evolution of tropical forestry and habitats; hence it included research sites in Trinidad, Porto Rico, British Virgin Island and Florida (Fig. 4.24). This project was funded by the United Sates Department of Agriculture Cooperative State Research, Education, and Extension Service USA.

Table 4.4 Changes in Land Cover from 1980 to 1994 (Al-Tahir and Baban 2005)

Change category	Hectares
Land to Mangrove	0.53
Water to Mangrove	13.96
Mangrove to land	22.69
Mangrove to water	4.58
Water to land	105.93
Land to water	0.12

Fig. 4.24 Fieldwork and Research in Puerto Rico

4.6 Land Use/Cover, Agriculture and Biodiversity Research in Australia

Once, I arrived in Australia, I realised the need for monitoring wetlands because it allows us to understanding and determine whether these ecosystems have changed over time in terms of size, extent and quality. Furthermore, their reliance on rainfall, surface runoff, groundwater levels and evaporation rates make them, and the ecological services they provide, vulnerable to even small climatic changes.

Natural wetlands constitute a major source of methane emission to the atmosphere, accounting for approximately 32 ± 9.4 % of the total methane emission.

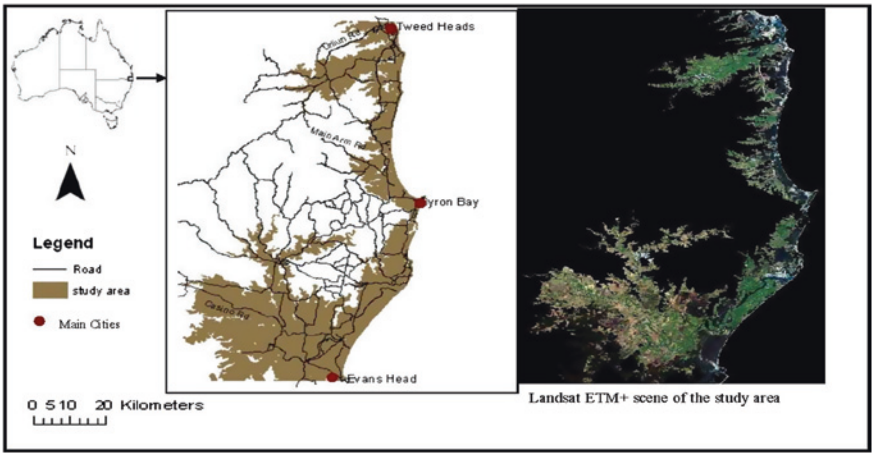

Fig. 4.25 The Study area, North-Eastern New South Wales, Australia (Akumu et al. 2010)

Estimation of methane emission from wetlands at both local and national scale using process-based models would improve our understanding of their contribution to global methane emission. My research team aimed to estimate the amount of methane emission from the coastal wetlands in north-eastern New South Wales (NSW), Australia, using Landsat ETM+ and to estimate emission with a temperature increase. Supervised wetland classification was performed using the Maximum Likelihood Standard algorithm. The temperature dependent factor was obtained through land surface temperature (LST) estimation algorithms. Measurements of methane fluxes from the wetlands were performed using static chamber techniques and gas chromatography. A process-based methane emission model, which included productivity factor, wetland area, methane flux, precipitation and evaporation ratio, was used to estimate the amount of methane emission from the wetlands. Geographic information system (GIS) provided the framework for analysis. The variability of methane emission from the wetlands was high, with forested wetlands found to produce the highest amount of methane, i.e., 0.0016 ± 0.00009 teragrams (Tg) in the month of June, 2001. This would increase to 0.0022 ± 0.0001 Tg in the month of June with a 1 °C rise in mean annual temperature by the year 2030 in north-eastern NSW, Australia (Fig. 4.25). This research was published in the *Remote Sensing Journal* (Akumu et al. 2010).

I also became interested in and wanted to study the effects of anthropogenic factors such as urbanisation, residential development and agricultural development on coastal wetlands in Australia using GIS. This research aimed to predict the potential impact of sea level rise (SLR) on the coastal wetland communities. Sea Level Affecting Marshes Model (SLAMM) was used to predict the potential impacts of sea level rise (Fig. 4.26). It was found that a meter rise in sea level could decrease coastal wetlands such as Inland fresh marshes from about 225.67 km^2 in February 2009 to about 168.04 km^2 by the end of the century in north-eastern

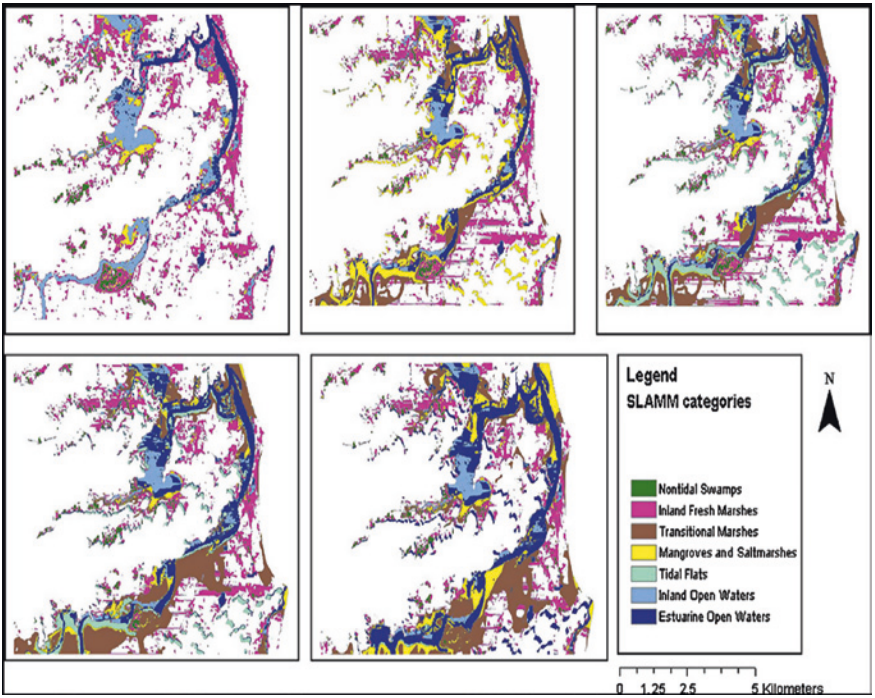

Fig. 4.26 The impact of sea level rise of about 1 m on the coastal wetland communities in north-eastern NSW by the year 2100. (Akumu et al. 2011)

NSW, Australia. The outcomes from this research can contribute to enhancing wetland conservation and management in NSW and was published in the Journal of *Coastal Conservation, Planning and Management* (Akumu et al. 2011).

4.7 Land Use/Cover, Agriculture and Biodiversity Research: A Conclusion

It has been acknowledged that access to up to date information on land use/cover and agriculture is critical for developing and monitoring land based resources and policy development as well as countering human induced influences. Consequently, mapping land use/cover and agriculture has gained approval as an effective tool for planning and management. However, conventional methods of mapping are labour intensive, time consuming and are concluded relatively infrequently. Remote sensing has emerged as a significant tool in this field. In fact, it has shown that remote sensing based land use/cover, agriculture and biodiversity mapping even at coarse spatial resolutions can provide key environmental information for scientific analyses, resource management and policy development at regional, continental and global levels.

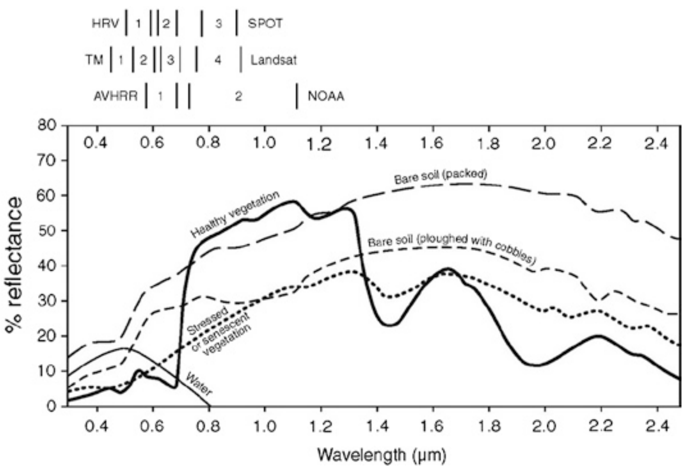

Fig. 4.27 Simplified spectral reflectance curves for land cover in An arid and semi-arid environments. Example spectral bands of SPOT, Landsat TM and NOAA satellite sensors are shown (Adopted from Abrams et al. 1984; Barrett and Curtis 1992; Harris 1991)

Fundamental to effectively using remote sensing in geo-based challenges related to land use/cover, agriculture and biodiversity analysis and applications is the understanding of 'Electromagnetic energy' and the information content in the 'spectral response' for each land use/cover types of interest .These can be explained as follows;

a. Electromagnetic energy reaching the earth's surface from the Sun is reflected, transmitted or absorbed by different land use/cover types on the surface of the earth such as soils, water, and vegetation.

b. Different land use/cover types on the surface of the earth as well as their various conditions (For soils: colour, moisture, organic and Iron contents; For Vegetation: type, leaving stage and stage of growth) through interactions with the Electromagnetic energy produces characteristic individual signatures that is described by the spectral response of that target. Hence, in principle, different land use/cover types and their 'conditions; can be identified from its spectral reflectance signature if the sensing system has sufficient *spectral resolution* to distinguish its spectrum from those of other materials.

This premise provides the basis for remote sensing mapping and analysis which is focused on obtained spectral signature at specific wavelengths. For example in the case of vegetation, vegetation has a unique spectral signature which enables it to be distinguished readily from other types of land cover in an optical/near-infrared image. The reflectance is low in both the blue and red regions of the spectrum, due to absorption by chlorophyll for photosynthesis. It has a peak at the green region. In the near infrared (NIR) region, the reflectance is much higher than that in the visible band due to the cellular structure in the leaves (Fig. 4.27). Hence, vegetation can be identified by the high NIR but generally low visible reflectance's.

My research in this field started with supervising a PhD project which offered me the opportunity to learn that developing tropical countries face unique development challenges arising from their small size and vulnerability to natural disasters as well as the resulting economic volatility. However, they tend to have a severe shortage of reliable land use/cover data sets despite the ongoing rapid rate of urbanization, population growth and the substantial expansion in industrial and agricultural development.

My major research has been focused on using remote sensing in mapping and examining and use\cover types as well as agriculture and showed that it possible to produce reasonably accurate maps for vegetation communities and other land use/cover types. I have also used the manipulation and analysis capabilities of GIS, in combination with remote sensing techniques, to provide a wider application for mapping and analysing land use/cover in tropical environments.

Evidently, to mange resources we need to understand them hence, I used the deductive geo-ecological research to increase our understanding of land use/cover distribution and to deduce the required BLU's for their preservation. In addition such analysis allows the formulation and implementation of environmental plans for, e.g., identifying suitable locations for reintroducing or introducing specific land use/cover types to specific areas on the island. Finally, I managed to develop my expertise in this discipline through involvement in supervising student projects, obtaining research projects and conducting consultancy activities in the UK, Malaysia, the Caribbean, Australia and more recently Kurdistan region in Iraq.

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Chapter 5
Suitability Science and Management

5.1 Introduction

My association with GIS based suitability analysis developed from being involved with supervising student projects whist working at Coventry University. Then I dealt with selecting potential sites for landfills and wind farms. Having seen the power that GIS encompass in terms of spatial and temporal analysis in this context, I used the same approach for modeling optimum sites for locating reservoirs in Malaysia and in modeling the optimum routes for linking the potential/proposed sites to demand areas. In the Caribbean region, I developed some work for locating wind farms and landfill sites.

This situation, has created a need for more consistent and objective methods for making decisions; improved access to, and better management of, environmental information. Geographical Information Systems (GIS) have the capability to store volumes of necessary multidisciplinary information, structuring and integrating a variety of economic and environmental constrains. Consequently, playing an important role as a decision support tool and as a means for improved management of environmental information regarding optimum waste site locations. However, involving GIS meant selecting the best quantitative and representative method for locating landfill sites. In researching this problem I learned that the two main methods used for sitting landfills are; *Voluntary Siting* (this method uses a sociological and political agenda). Here, the protection of the environment and human health become the responsibility of site design and management, as opposed to the in situ abilities of the site to do so. The other method is *Market Based Siting*, which allows residents in the required area to vote to accept a site in return for financial compensation, the amount of which is determined by them. Both of these methods seemed frivolous as they attempt to solve the problem from one viewpoint, i.e. satisfying the public. This strategy is politically correct but not necessarily an optimal one in environmental, technical and economical terms. Then I learned about *Planning Criteria Methods* (site selections based on the following siting constraints: physical, safety, environmental, political and technical).

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The World Health Organisation (WHO) has developed a recommended set of exclusionary criteria based on unstable or weak soils, subsidence, saturated soils, surface water areas, major natural hazards, historic locations and sensitive locations (Sloan 1993). This approach can successfully provide the physical requirements when choosing a site but unfortunately, it gives very little, if any, indication of the preferred conditions. A progression on the WHO method can be found in Australia, where the Melbourne and Metropolitan Board of Works has developed criteria that include preferred as well as exclusionary criteria based on topography, surface soils, atmospheric conditions, recreational value, population density, water supply and public acceptability. In the United States, siting guidelines have been developed by individual states. For example, siting conditions devised by New Jersey are precise (they define both desirable and unacceptable conditions for the following factors; geologic, physiographic, hydrologic, climatologic, transportation, resource, human environment and biological considerations) and are enforced rigorously. Some researchers have endorsed the use of flexible methods to ensure sensitivity to local circumstances and attempt to overcome possible limitations through site design, modifications and management (Din 1993). Planning Criteria, methods are comprehensive, as they are environmentally and geologically sensitive and safe, economically practical and politically acceptable to the public. Therefore, this approach was used in the study.

My Geosciences background was helpful with making a contribution to the discipline through involvement in research projects in the UK, Malaysia and the Caribbean. The sections below will provide details of this work.

5.2 Suitability Science and Management in the UK

5.2.1 Selecting Potential Landfill Sites

In the past, as household wastes were burned in open fires and stoves, most municipal wastes disposed of were the ash by-products from burning. This situation changed with the introduction of the clean air act in 1954, which limited the amount of smoke that could be emitted from a chimney. After the introduction of this law, people were forced to dispose of wastes in dustbins as opposed to burning them. This increased the volume of municipal wastes to be dealt with. To cope with the disposal problem, local authorities created large landfills. Since the 1950s and the clean air act, the absolute amounts of waste disposed of have increased substantially; with the UK presently creating thirty million tonnes of household waste every year. This increase partly reflects changes in patterns of consumption. Despite attempts to do more with the waste society creates, the bulk of waste still ends up in the ground. Indeed, as Holmes (1983) points out, "all methods of waste disposal are, in the final analysis, landfill." This is because even when wastes are treated to reduce volumes or burned to produce energy, there are still residues that can only be disposed of in the ground. Therefore, the waste is now a bigger problem than ever and for the foreseeable future, land filling will remain the primary means of waste disposal in the UK (NRA 1992).

Increased environmental awareness and deepening environmental concerns in recent years has forced attention on the need to move towards a more sustainable society. These changes in attitudes have been supported by recent changes in National and European laws and policies regarding the environment and waste disposal. These include the Environmental Protection Act 1990; the Water Resources Act 1991 and the more recent Environment Act 1995. In this context, the pressures and requirements placed on decision makers by government and society have increased, as they now have to make decisions taking into considerations public satisfaction, environmental safety and economic practicality. This situation has created a need for more consistent and objective methods and technologies such as Geographical Information Systems (GIS) for making scientific and sustainable decisions.

This research aimed to develop and employ a simplified landfill location constraints criteria for the UK based on; the criteria used by other countries and International Organisations; current National and European legislation and policies on waste disposal, in particular, waste disposal by land filling; current legislation and policies followed by various public and private sectors in locating landfills sites. The developed constraints criteria will be implemented to identify sites suitable for locating a landfill site in the south Warwickshire area using GIS. A questionnaire targeting relevant public and private sectors in the UK has revealed that the constraints criteria used are usually client led and locally determined, but are based on planning policy guidance and some EU laws and directives. Using this information, and landfill criteria used elsewhere around the world, a simple Geographical Information Systems (GIS) assisted landfill location constraints criteria was developed for the UK by taking into consideration all relevant environmental, planning and resources constrains. The model also allows for the introduction of further constraints (such as public opinion) should it be necessary. A case study, in the English Midlands, is used to implement the developed constraints criteria. The GIS (IDRISI) was used to convert and integrate the data, then distance operations and overlay modules were used to construct a suitability map. This map composed of classes from 0–10, where 0 represents ideal locations and 10 represents unsuitable areas for locating landfill sites (Fig. 5.1). Evidently, this map represents a practical tool for sitting optimal location, as it account for and summarise all necessary conditions, therefore assisting in the decision making process. The outcomes were published in the *Planning Practice and Research Journal* (Baban and Flannagan 1998).

5.2.2 Locating Wind Farms

Lately there has been an increased awareness of environmental degradation caused by anthropogenic activities such as greenhouse gases and acid rain (Van Ettinger 1994). As the negative impact of traditional power generating methods, principally

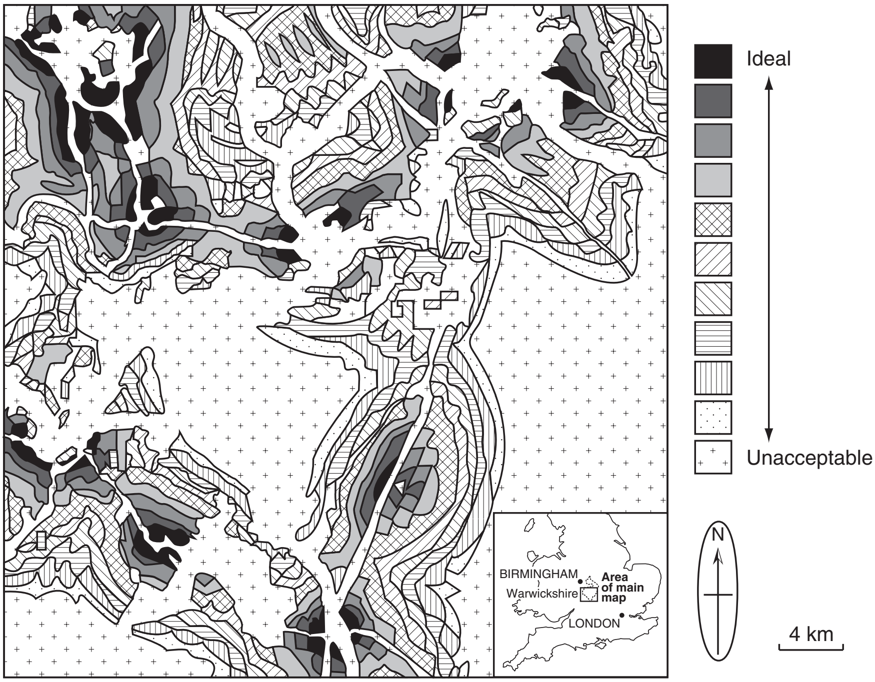

Fig. 5.1 Landfill site suitability in Warwickshire, UK

coal and oil-fired power stations, on the environment is visibly significant, the demand for more environmentally friendly renewable energy is also growing. Consequently, these demands have been supported by recent changes in international and national laws and policies including the Rio Summit (1992) and Kyoto (1997). In the EU a number of similar programmes were set up including the Altener Programme and the Declaration of Madrid. These programmes aim to treble renewable energy sources, reduce carbon dioxide emission levels and promote collaborative efforts to substitute the equivalent of 15 % energy demand in the EU with renewable energy sources (EWEA 1996). In the UK, non-fossil fuel electricity production has been assisted with a toll paid by electricity generators from fossil fuels according to the Non Fossil Fuel Obligation (NFFO) in the Electricity Act of 1989.

In recent years, these factors have stimulated the development of various renewable energy technologies. Wind power is one such form of renewable energy that is expected to encounter widespread commercial success. This is mainly because wind energy can be economically viable and does not produce any physical pollution. In fact, using wind to replace just 1 % of the EU's fossil energy production would avoid an annual emission of 15 million tons of carbon dioxide (Garrard 1994), therefore contributing significantly to the much-needed reduction in air pollution.

This growth would inevitably be accompanied by planning and environmental restrictions and conflicts, which will mainly stem from the process of selecting suitable locations to site wind farms. These farms, in addition to being economically viable, should have an insignificant impact on the local environment in terms of visual and noise intrusion, electromagnetic interference and possible wildlife collisions. Successfully managed growth will therefore require taking all the relevant factors into consideration and using an objective method for locating wind farms. Geographical Information Systems (GIS) have the capability to handle and simulate the necessary physical, economic and environmental constraints. Consequently, GIS can play a significant role as a decision support tool regarding optimum wind farm locations.

A project student, Tim Parry, whilst training with the planning department at Coventry University developed an interest in this topic and asked me to supervise his final year project on combining planning with the environment. Then, we developed a project on a GIS based approach to wind farms. The purpose being to gain an understanding of the criteria used in determining site suitability for wind farms in the UK, to develop a simplified GIS-assisted wind farm locating criteria in the UK, and to use this criteria to evaluate its performance. In this project, a questionnaire targeting relevant public and private sectors in the UK revealed the lack of coherent national criteria for locating wind farms. Using information from the questionnaire and the available published literature, a simple GIS-assisted wind farm location criteria was developed for the UK. A GIS (IDRISI) was employed to apply these criteria using two different methods to combine information layers for a site in Lancashire. The first considered all the layers as being equally important and gave them an equal weight. The second grouped the layers and graded them according to perceived importance. The outputs were composed of classes from 0–10, where 0 represents ideal locations and 10 represents unsuitable locations. Using the second method resulted in a slight increase in the geographical extents for the most suitable sites. These maps can be used to assist in the decision making process when locating wind farm sites (Fig. 5.2). This research was published in the *Renewable Energy* Journal (Baban and Parry 2001).

5.3 Suitability Science and Management in Malaysia

5.3.1 Locating Reservoirs Sites

Further to my involvement with Malaysia as indicated in Chaps. 4 and 5. Langkawi Island faces the possibility of having water shortages in the future; building reservoirs has been promoted as a possible solution to meet future demands for water supply. In addition, an issue that has concerned me was the impact of using various methods for combining data sets. Here I had an opportunity to test the idea whilst identifying Optimum Sites for Locating Reservoirs.

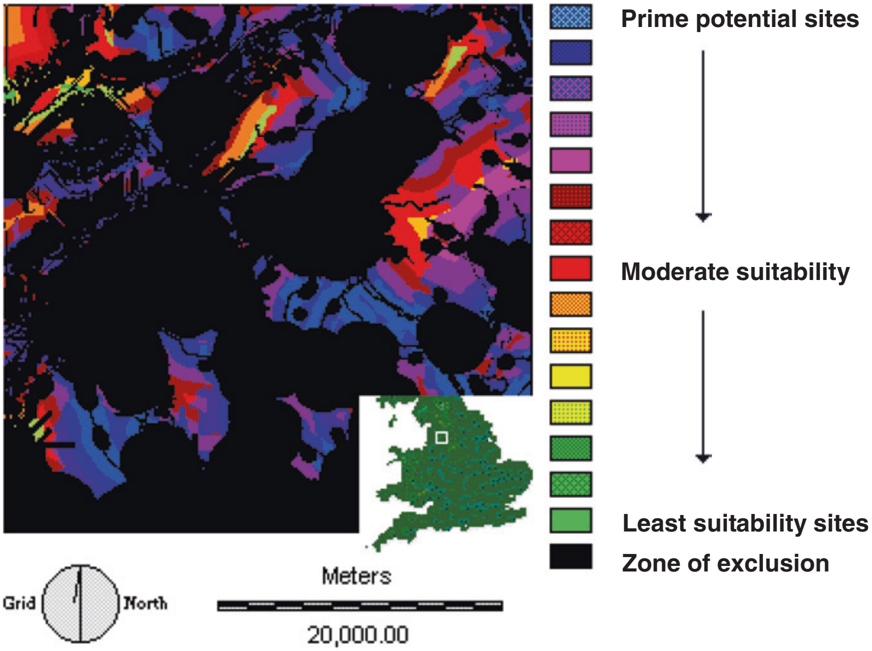

Fig. 5.2 GIS based approach to locating potential sites for wind farms in Warwickshire, UK (Baban and Parry 2001)

In this study, criteria were developed and implemented, using two different methods, combining the use of various data sets to locate potential sites for reservoirs in the Langkawi Island, Malaysia based on all relevant factors including: topography, geology, hydrology, location in relation to both abstraction and supply points, land use/cover types and settlements. In this research, satellite imagery and digitized geological and elevation maps were utilized to generate the necessary data layers for the developed criteria. Then IDRISI, a raster based GIS was employed to implement the criteria using the Boolean and the Weighted Linear Combination (WLC) methods. The Boolean method produced five reservoir sites with the 70 Mld water capacities, two of which corresponded well with a field-based study. Whilst the proposed site with the 90 Mld water capacity did not correspond with the field based study. The WLC method produced five sites with the 70 Mld water capacities, three of which matched those of the field study. Whilst for the 90 Mld water requirement, two potential sites were produced and both have matched those of the field study (Fig. 5.3). The outcomes indicated that the developed criteria were sensitive to physical, environmental and economical settings on the Langkawi Island. Furthermore, GIS and remote sensing can be useful tools for generating, manipulating and handling relevant data layers and ultimately providing management options for decision makers. This research was published reporting the preliminary outcomes as a conference paper in the *proceedings of the 21st Asian Conference on Remote Sensing* (Wan-Yusof and Baban 2000), as conference

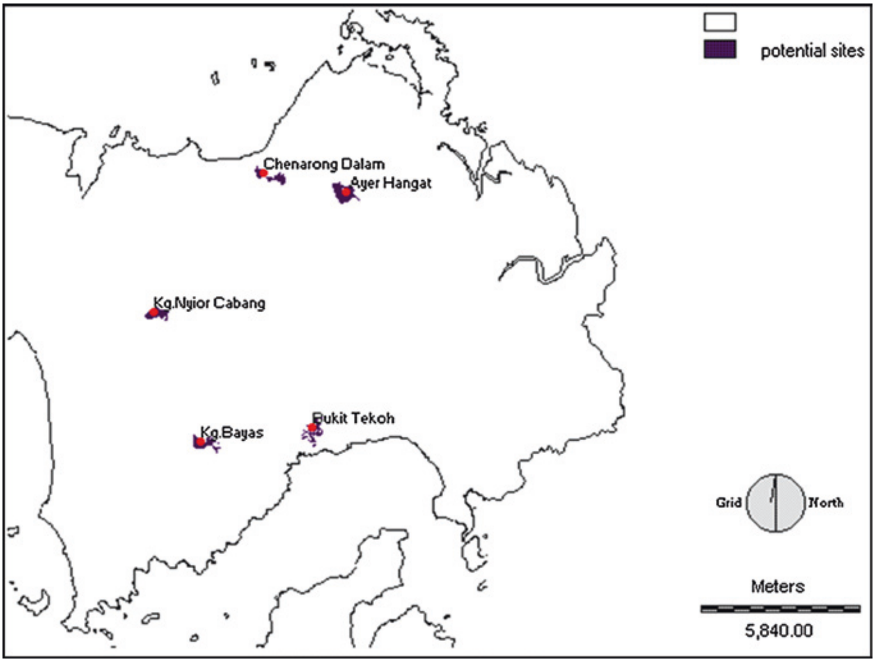

Fig. 5.3 Potential reservoir sites using Boolean method (Baban and Wan-Yusof 2003)

paper the 19th Conference of Asian Federation of Engineering Organisation (CAFEO, "Information and Communication Technology (ICT) in Development—The Challenges Ahead", 110–115, Brunei Darussalam (Wan-Yusof et al. 2001), also published as part of the Proceedings of the Second World Engineering Congress, Water Engineering and Geomatics in Malaysia using 2002 (50) and in an extended form in the *Journal of Water Resources Management* (Baban and Wan-Yusof 2003).

5.3.2 Identifying Optimum Pipeline Pathways

As a follow on from the reservoir siting research, it became necessary to map and identify efficient pathways to link the potential reservoir sites to demand areas. Hence, we set out to model optimum routes for linking potential reservoir sites to demand areas on Langkawi Island. In this research, using GIS, we developed and simulated options for locating optimum pipeline routes for linking two proposed reservoir sites to future demand areas in Langkawi Island, Malaysia. A basic pipeline locating criteria was developed based on land use, terrain, geological, and environmental factors. IDRISI GIS was used to geographically associate this information with individual land use/cover types on the island. Then, a friction

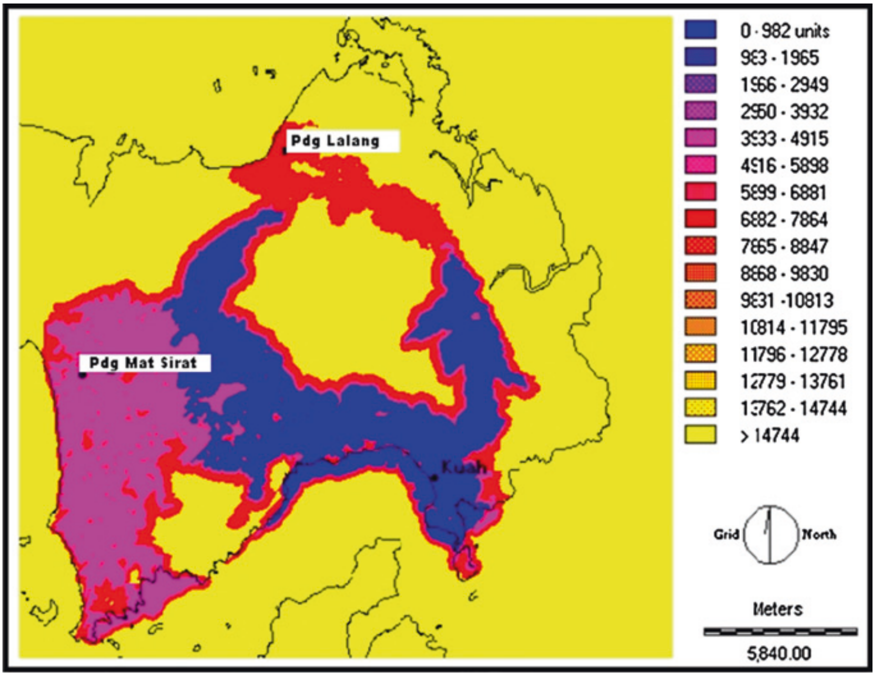

Fig. 5.4 Cost-friction surface value units for Kuah town (Baban et al. 2004)

surface cost-value and a friction surface were created (Fig. 5.4). Subsequently, two alternative scenarios were established and implemented (Fig. 5.5). The results from both scenarios show that the paths will pass through the lowest friction surface value, i.e. grassland and mixed horticulture (Figs. 5.6 and 5.7). The results from both scenarios were evaluated against straight-line paths. The analysis shows that a straight-line path may not necessarily be the cheapest distance in mountainous tropical environments. This study has demonstrated the advantages of using the shortest and most effective route in developing and simulating different options for finding optimum paths and providing reliable management options for decision makers. This study has demonstrated the advantages of integrating remotely sensed data sets at 30 m resolution in combination with GIS analysis in delineating a least-cost pipeline route for the chosen reservoirs to their target areas. These tools are very useful for providing viable options to decision makers. This research was presented and published in the *Proceedings of the 7th Annual International Conference, Map India 2004* (Wan-Yusof and Baban 2004) and later in a comprehensive form in *Journal of Surveying and Land Information Science* (Baban et al. 2004).

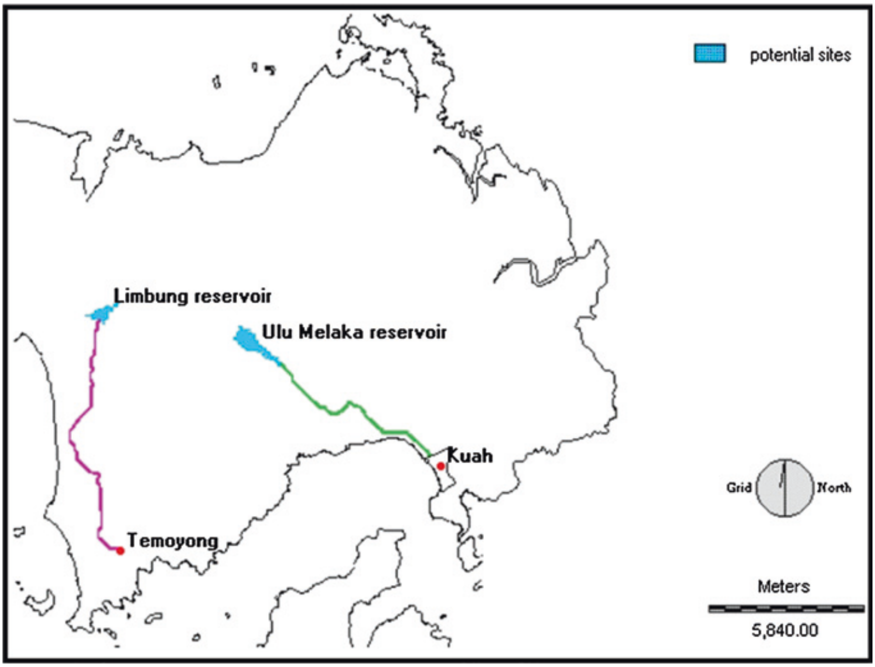

Fig. 5.5 The proposed pipeline path from the Limbong reservoir to Temoyong and from the Ulu Melaka reservoir to Kuah town (Baban et al. 2004)

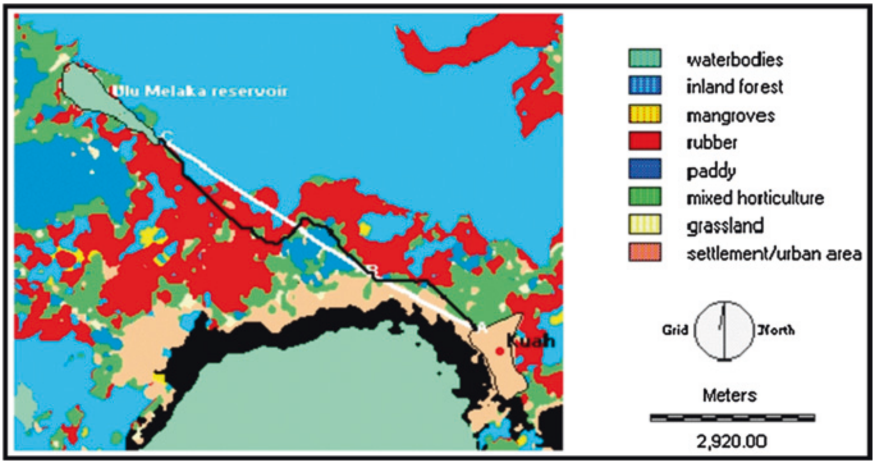

Fig. 5.6 A comparison of the pipeline path between scenario 1 (*white*) and scenario 2 (*black*) from the Ulu Melaka reservoir to Kuah town (Baban et al. 2004)

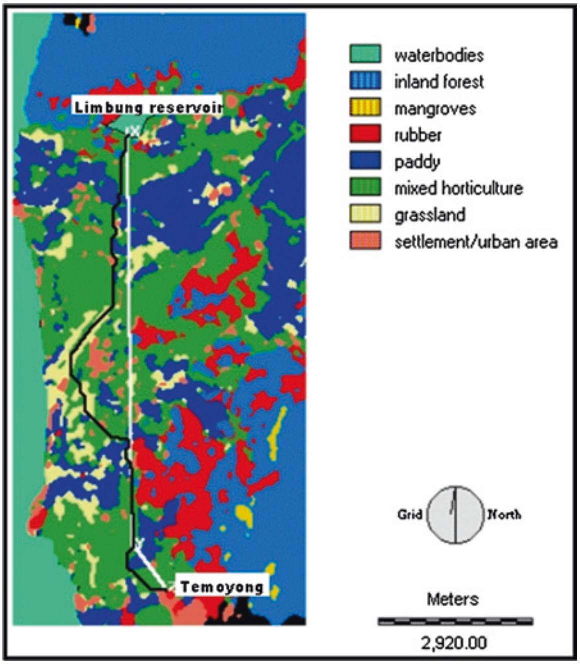

Fig. 5.7 A comparison of the least-cost pipeline path between the straight-line (*white*) and the computed path (*black*) from the Ulu Melaka reservoir to Kuah town resort area (Baban et al. 2004)

5.4 Suitability Science and Management in the Caribbean

Further to my previous research in the Caribbean as stated in Chaps. 4 and 5.

5.4.1 Locating Wind Farms

Recently there has been an increased awareness of environmental degradation caused by greenhouse gases and acid rain because of anthropogenic activities. The negative impact of burning fossil fuels on the environment is increasingly becoming evident and the demand for more environmentally friendly renewable energy is growing. Consequently, these demands have been supported by recent changes in international and national laws and policies.

In the Caribbean Region and in Trinidad and Tobago by definition, wind energy has neither been harvested nor investigated seriously despite its great potential in terms of magnitude as well as economic and environmental benefits. However, planning and decision making in this regard is seriously compromised due *information poverty,* i.e. the lack of data and effective and reliable information for decision-making. I became involved in developing a Geoinformatics based approach to locate wind farms in the Caribbean region focusing on Trinidad and Tobago as a case study.

This research advanced a methodology to endure *information poverty* and to identify and map the optimum locations for locating wind farms in the Caribbean region, through examining Trinidad and Tobago as a case study. The methodology is based on using Geoinformatics to utilise available and reliable cutting edge technology such as satellite remote sensing, global positioning systems and geographic information systems to originate, develop, supplement, manage and analyse the necessary data sets for locating wind farms in the Caribbean region.

This scientific approach will enable resource managers to make informed decisions by taking physical, environmental and political factors into account. Furthermore, it will enable them to target their limited financial resources to those areas, which hold most promise, and to develop and test various management scenarios to find acceptable solutions to overcome foreseen challenges. Aspects of this research were published in the *Proceedings of the Second Caribbean Environmental Forum and Exhibition (GEF-*2*),* which was held in Trinidad during 2004 (Baban 2004a).

5.4.2 Locating Landfill Sites

Despite an increase in alternative technologies and techniques for the management of solid waste, the practice of waste disposal through landfill sites remains the most applicable both worldwide and in the Caribbean region for the foreseeable future. The development of scientific criteria to objectively locate optimum landfill sites in the Caribbean region is dependent on several factors with differing spatial variability. Information poverty issues in the region could seriously hinder such badly needed development.

The proposed concept is a Geoinformatics based approach for locating landfill sites in the region. The proposed approach promotes the use of Geoinformatics to manage the information poverty challenge through developing the missing but essential data sets as well as carrying out the necessary analysis. The applicability of the concept was examined through reviewing a case study in the UK. The proposed approach is flexible which makes it useful as a planning tool as it provides the user with the freedom to employ their individual local, national and regional expertise in the decision making process. Additional relevant transient layers of information, such as public satisfaction, could be easily integrated into the approach and, consequently, be taken into consideration when required. Furthermore, the recommended approach is also scientifically justifiable, open to scrutiny and will lend itself to public acceptance. As a recommendation, I indicated that landfill site location investigations in the Caribbean region could be taken a step further by using GIS to assist in locating the optimum site amongst several of the "most suitable" sites from the constraint map by assessing their suitability on an individual basis. Moreover, it is also possible to determine the optimal size and number of landfill sites in each geographical area, based on potential natural growth as well as demographic shifts in population due to employment

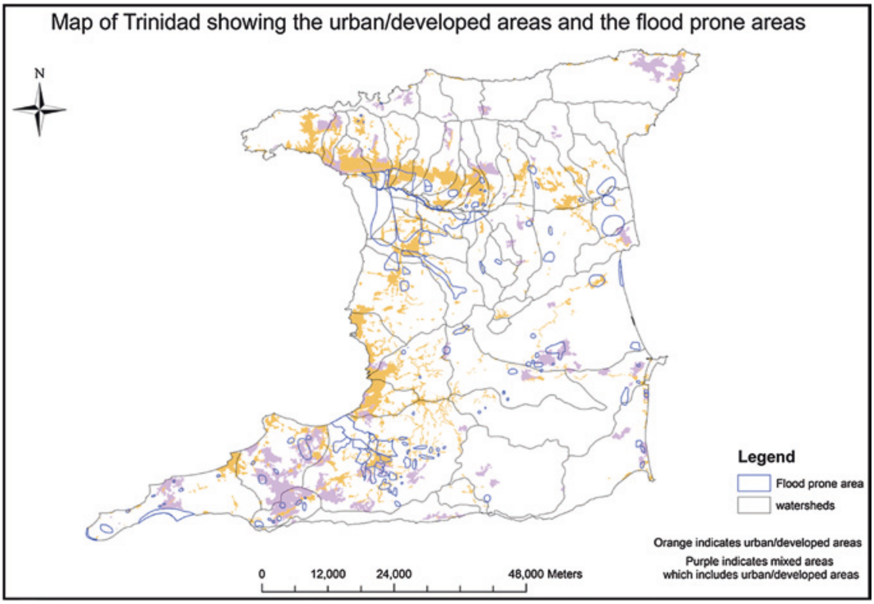

Fig. 5.8 Urban/developed areas (*orange*), mixed urban/developed areas (*purple*), watersheds (*black*) and the location of the flood prone areas (*blue*). It can be seen that areas which are developed or partially developed are prone to floods (Baban and Kantasingh 2008)

and so on. Aspects of this research were presented in two international conferences and were published in two conference proceedings; *the Second Caribbean Environmental Forum and Exhibition (GEF*-2*)*, which was held in Trinidad during 2004 (Baban 2004b) and *the Urban and Regional Information Systems Association Conference, URISA's 2006 Caribbean GIS, which was held in the Bahamas during 2006* (Baban 2006a, b).

5.4.3 Locating Flood Prone Areas

This research was based on the concept of determining the limits of tolerable change within hydrological catchments before the intensity/duration thresholds of rainfall for triggering floods. The available datasets, including historical data, were reclassed to indicate runoff or infiltration rates and the percentage of each characteristic for the watersheds affected and not affected by floods was examined and compared. The outcomes showed that the watersheds of larger area and less steep slopes were more prone to floods (Figs. 5.8 and 5.9). Further examinations revealed that Slope, Elevation and Land use/cover were sufficient to be indicators for Carrying Capacity (Fig. 5.10). This research was presented and published by the Second International Conference on Geoinformatics Technology for Natural

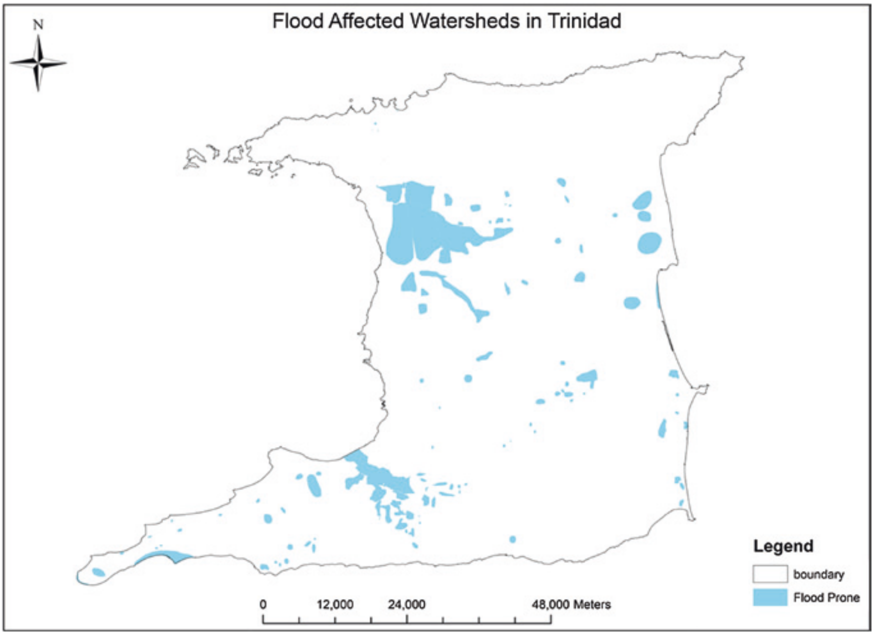

Fig. 5.9 Flood prone areas in Trinidad (Baban and Kantasingh 2008)

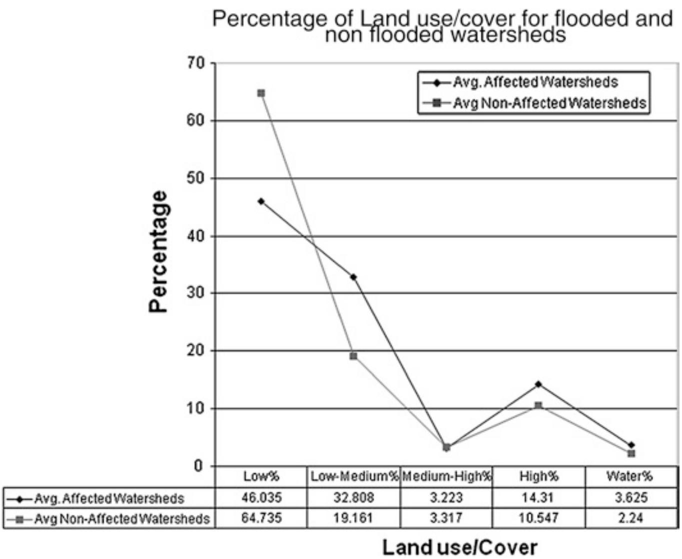

Fig. 5.10 In terms of carrying capacity, this figure shows the relationship between the flooded and non flooded watersheds (Baban and Kantasingh 2008)

Disaster Management and Rehabilitation, pages 100–106. This was held by the Asian Institute of Technology (AIT), Bangkok, Thailand during 2008 (Baban and Aliasgar 2008). It was also published with a focus on Geoinformatics as an approach (Baban and Cannisus 2008).

5.4.4 Locating Critical Slopes

This research is based on advancing a deductive approach for studying landslides founded on the concept that *conditions at known landslide sites within an area are reliable indicators of where future slope failures might occur* (Baban and Sant 2004).

The initial stage of determining the favorable factors influencing landslide occurrence was conducted via several site visits to various areas affected by landslides. The Trinidad and Tobago National Emergency Management Authority Disaster and Response Map provided guidance in selecting locations for visits. The site visit recorded the spatial distribution of landslides, types, general conditions and where possible the trigger. The identified factors (or parameters) that affect landslide occurrence in the study area based on previous work (Baban and Sant 2004; Sant and Baban 2004) and field visits were slope, aspect, geology, soils, rainfall and land cover/use.

The development of a landslide inventory was based on a 1995 published NEMA Disaster and Response map for Tobago that indicated the location of landslide locations within the study area. To support this inventory, a field survey was conducted in May of 2002 to determine the location of recent landslides within the survey area. This survey utilized GPS and traditional field measurement techniques, using radial compass bearings and distance measurements from a GPS station, to quantify the location, orientation and planimetric extent of landslides located. The landslide inventory was also supplemented by using orthorectified aerial photography to identify and measure landslide locations. These three data sources formed the basis for the landslide inventory data theme developed in this analysis. The field inventory incorporated all landslide types (debris flows, shallow slides and rock falls).

A multi-factor layer combination sequence was used to effect the identification of critical slopes in the study area (Fig. 5.4) within a vector GIS environment. The landslide inventory was used to extract the specific range of conditions at known landslide sites for each identified data theme/factor that could influence landslide occurrence. Extracted landslide prone conditions for each condition theme were then combined to determine the exact combination of conditions and the range for each condition that existed at known landslide sites. This process facilitated the determination of the unique combination of the landslide prone conditions.

By determining which combination of the parameters were present at known landslide sites a prediction of the location of potential landslides could be proposed by determining where similar combination of conditions were present

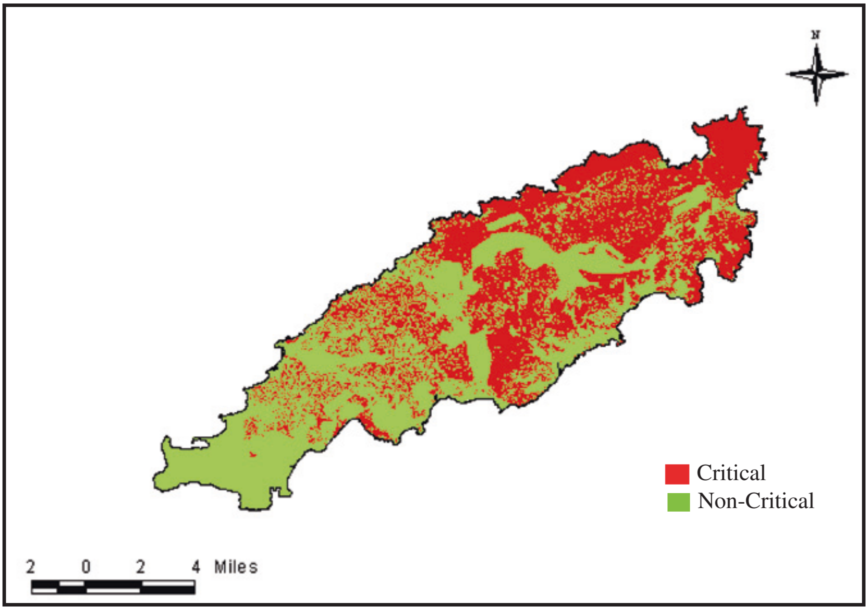

Fig. 5.11 Landslides prone areas in Tobago (Kantasingh and Baban 2004)

within the study area. Landslide critical slopes showed a frequency of occurrence of some conditions above others within each of the parameter themes used in the analysis. The developed landslide critical slopes map (Fig. 5.11) indicates that the south west part of the island was devoid of critical slopes and in moving from south west towards the north east part of the island of Tobago the amount of critical slopes increased and became the prevalent slope type towards the north east portion of the island.

This research was presented in a A workshop Organised by the Center for Caribbean Land and Environmental Appraisal Research (CLEAR), UWI, December 2004, Learning Resource Center, St. Augustine, Trinidad. Trinidad and Tobago (Sant and Baban 2004).

5.4.5 Locating Suitable Agricultural Land

Agricultural land suitability for Tobago (Fig. 5.12) and Trinidad (Fig. 5.13) was developed as a part of a study commissioned by the Town and Country Planning Division (TCPD), a Division in the Ministry of Housing and Settlements to identify suitable and unsuitable areas for development on the hillsides of Trinidad and Tobago. This project, guided by the Technical Working Group (TWG) which comprised of Town and Country Planning Division staff, experts from several other

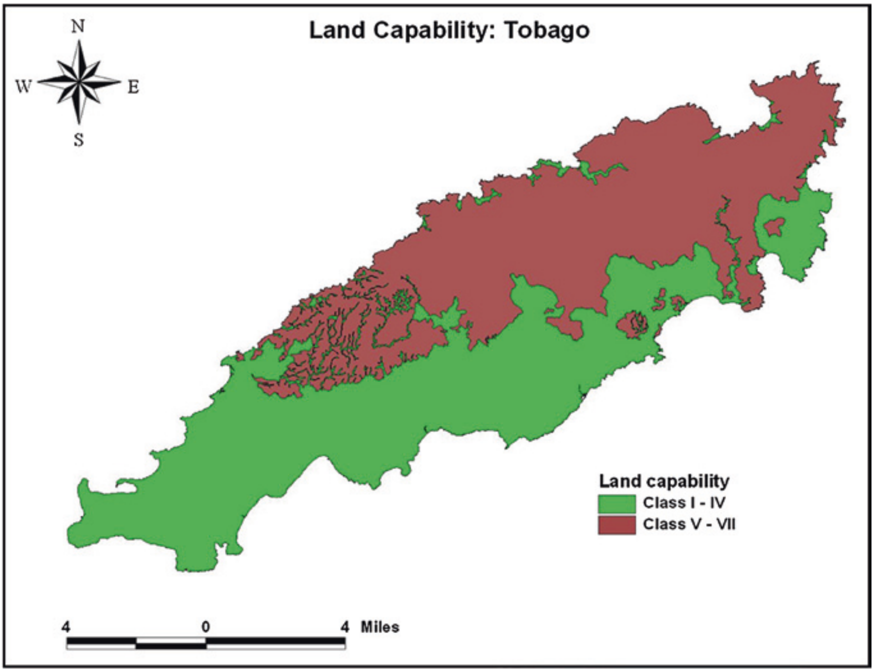

Fig. 5.12 Land suitability for agriculture in Tobago (Baban et al. 2006a, b)

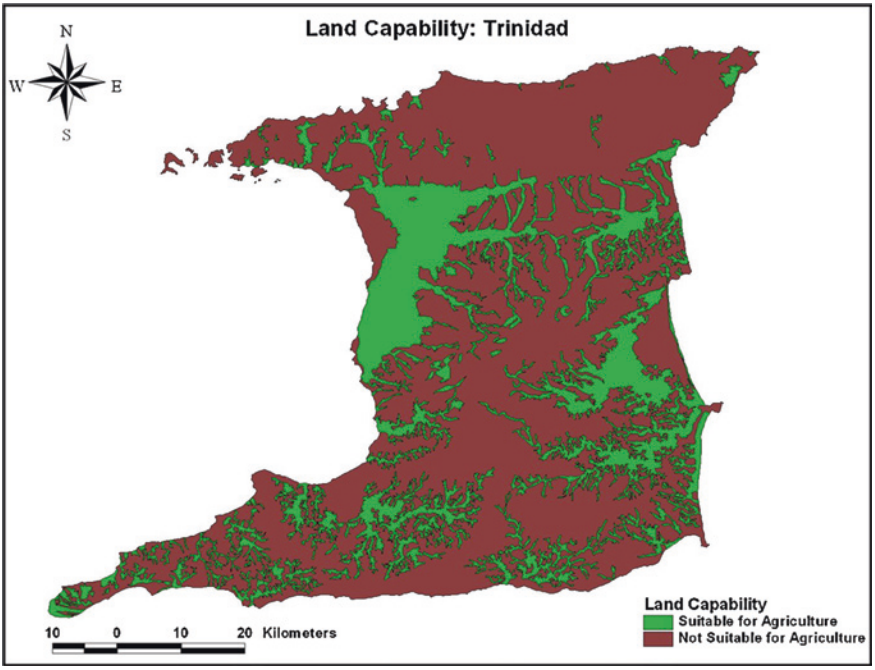

Fig. 5.13 Land suitability for agriculture in Trinidad (Baban et al. 2006a, b)

organizations and a research team from CLEAR, developed a GIS based approach for managing hillside development in Trinidad and Tobago. A methodology for generating a GIS based system using *Microsoft Access 2000* and *Arc/View* to implement the established suitability criteria was developed and used. The system is designed to prohibit development at protected areas such as suitable land for agriculture (land capability class ≤ IV) (Baban et al. 2006a, b, 2007).

Criteria justification from a resources and planning viewpoint, it is impractical to locate development on prime agricultural land, as most of the areas of fertile agriculture lands in Trinidad and Tobago are already under threat of urbanization. Therefore it is necessary to introduce some protection for converting agricultural land for further development. Based on Hardy (1974), lands in capability classes of I, II, III and IV are suitable for agriculture and above IV are not suitable for agriculture therefore it can be used for built development. However, capability classes above IV are well suitable for specific agriculture crops and may not be very suitable for built development. For example, the description of classes V and VI indicates that these lands should be left under indigenous growth of forest and the class VII land has greater erosion potential (Hardy 1974). Aspects of this research was funded by two consultancies by the Ministry of Planning and Development of Trinidad and Tobago, the first focused on Managing Hillsides and the second on Developing an up to date Land use Map based on satellite imagery and remote sensing methodologies.

5.5 Suitability Science and Management in Australia

5.5.1 Locating and Managing Vulnerable Areas to Coastal Erosion

My involvement started with an invitation by the Darwin City Council which commissioned us during 4th–8th February 2008 to visit Darwin and examine coastal erosion problems at two locations, namely, the East Point and Nightcliff coastal areas (Baban et al. 2008; Pathirana and Baban 2008; Jones et al. 2008).

i. Field based Examinations

The field visits showed two sets of processes leading to coastal erosion, namely, Sea based process and Land based process and as follows;

At the East Point Location
The processes can be categorized into:

a. Sea Based Processes

Severe erosion is evident in many places, indicating that erosion is an ongoing process caused by wave energy, leading to the formation of small, medium and large caves, up to 8 m in height and 8 m in depth at the base of the cliffs

Fig. 5.14 Cave formation at East Point aligned in westerly orientation to ocean waves (*top*), erosion due to freshwater flows from cliff top (*middle*), erosion along deep cracks and joints; and collapsed section of cliff (*bottom*) (Jones et al. 2008)

(Fig. 5.14). The caves tend to have a due westerly orientation, which is consistent with the wave direction and alignment in the area. The caves, once they reach a critical dimension can collapse under the force of gravity and form embayment's or pocket beaches a long the shoreline. At high tides there is a concentration of wave energy in the embayments which tends to accelerate the natural erosion processes.

b. Land Based Processes

At this location, the team noticed an association between erosion and storm water, groundwater and surface freshwater flows. The embayments has groundwater seepage and in some cases quite high flows of water. In some other cases groundwater and surface water flows which are likely to be nutrient-rich and acidic are cutting deep channels in the rocks perhaps due to chemical reactions. We noticed that groundwater, stormwater and surface water flows have cut channels on the cliffs often along cracks, joints and contacts between layers, isolating sections of rock which become more susceptible to wave action and collapse.

At the Nightcliff location

Overall Cliff erosion by the ocean seem to be severe. The erosion, occurs in stages and is often worsen by fresh surface, groundwater and stormwater flows removing soft materials form the fissures and cracks within the rock. As the process continues the fissures become larger and detach segments of rock from the parent material.

a. Sea Based Processes

Severe erosion is evident at many places due to deeply weathered cretaceous strata and the abrasion-platforms indicating that erosion is an ongoing process caused by wave energy. In this location, the softer alluvium (coffee rock) layer offers little resistance to the waves, and seems to retreat in a uniform fashion. At high tide swell waves break on the cliff face exerting large forces and further break the joints until eventually large sections of rock fall out from the cliff onto the rubble beach forming high tallus build-up.

b. Land Based Processes

Surface fresh water runoff, stormwater flows and inadequate drainage systems cause gulling and erosion of the softer cliff carbonates and coffee rock, isolating sections of rock and coastline which become susceptible to erosion and collapse (Fig. 5.15).

ii. Remotely Sensed Analysis

Two sets aerial photographs of 1969 and 1978 as well as 2006 quickbird satellite images were available for the study. These were geometrically corrected, based on field based GPS readings, analysed and the eroson rates were estimated for the study area over time. For example, at the Nightcliff Aquatic Centre (Fig. 5.16) the erosion estimates are quite significant at sites 1, 2, 3, 7, with lesser erosion at sites 4, 5, 6 from 1969 (blue) to 2006 (orange). Similar findings from 1978 (white) to 2006 (orange) for sites 1, 2, and 3; but lower erosion rates at sites 4, 5, 6, 7 (Pathirana and Baban 2008; Baban et al. 2008; Jones et al. 2008).

Overall, the study revealed that at certain points along the coastline at East Point and Nightcliff erosion ranged from 1.9–17.3 m over a 28 year period with an average shoreline recession of 0.2–0.4 m per year or 30 cm per year. Erosion was categorised into low (0–5 m), medium (5–10 m) and high (10–15 m) erosion rates. At East Point erosion was low at eleven sites examined and medium at five sites. At eight sites examined at East Point Reserve (South) five were in the medium erosion category, one in the high and two in the low category. At East Point Reserve (West) twenty seven sites were examined. Five sites displayed medium erosion, with three sites 7–0 m from the road; and one site displayed the highest erosion and was only 3 m from the road. At Nightcliff 15 sites were examined with most displaying medium erosion rates (12 sites), with two sites in the high erosion category and one site in the low category. Three sites in the medium category were only 9–13 m from the road. Higher resolution analysis at both sites gave similar results. The calculated erosion rates are only estimates and in terms of decision making carry a low to medium level of accuracy. This is because of several issues with the remotely sensed data and the limited time to conduct field investigations. However, a coastline recession estimate was made at East Point

Fig. 5.15 Erosion from surface runoff and large stormwater outlet-Nightcliff (*top*), complete cliff erosion (*middle*) and serious coffee rock cliff erosion close to apartments (*middle* and *bottom*), yellow sandstone-dolomitic layer (*bottom*) (Jones et al. 2008)

Reserve (West) where artillery had been dumped over the cliff edge in 1945. This estimate was 15 cm per year, and is of the same order to our average erosion estimates determined using remotely sensed data of 30 cm per year. It is also important to realise that these coastal erosion estimates are site specific estimates and cannot be applied to the whole coastline of the two areas studied.

Although the average erosion rate for the two sites (30 cm per year) is not extreme, from time to time parts of the shoreline could recede by 5–10 m over a period of weeks, particularly during intense storm events. If estimates of coastal inundation are applied to current projections of sea level rise (3 mm per year), then

Fig. 5.16 Erosion rates around the Nightcliff Aquatic Centre 1960 *blue*, 1978 *white*, 2006 *orange* (Jones et al. 2008)

in a decade at some sites coastal inundation could be as high as 3 m in addition to the current erosion estimates, which means that some sites could be highly vulnerable. Cliff erosion at both sites is a natural process but can be seriously enhanced by surface, stormwater and groundwater flows at particular points over the cliffs which dissolve the fragile carbonate/silicate rocks forming large cracks and fissures which can cause cliff instability. There are several points at East Point and Nightcliff where stormwater outlets are sited near or close to the highly erodible cliffs and this is increasing cliff erosion. This suggests a stormwater management plan needs to be implemented to lessen cliff erosion. Natural erosion from the ocean is also occurring and can form caves up to 8 m high and only a metre from the cliff surface presenting a potentially dangerous situation, when coupled with erosion from man-made activities. Remedial works have been undertaken at East Point Reserve, but these need to be improved. It is suggested that Council should immediately develop a long term strategic coastal management plan to manage shoreline erosion and recession at East Point and Nightcliff, identifying the most vulnerable areas of erosion and potential cliff collapse; as well as assessing the affects on important infrastructure in the two areas. The report recommends producing a reliable coastal erosion risk map for Darwin from a multidisciplinary study that involves long-term monitoring of the erosion along the coastline and an assessment of the potential effects on this erosion from enhanced or extreme weather events. If coastal protection options are to be considered there would need to be more study of wave conditions and effects of extreme events to allow preliminary design and costing of coastal engineering solutions (Pathirana and Baban 2008; Baban et al. 2008).

The team suggested several management scenarios for remedial works such as the ‘Business as usual Scenario’, no action is required; ‘Boulder Wall Structures’; designing and constructing a boulder wall along parts of East Point and Night cliff, to effectively protect the cliff face from the ocean; ‘Rubble Mound Structures’, a lower cost option could be to locate rubble mound structures across the front of parts of the coastline which are showing severe erosion symptoms and which are perceived to be of economic, environmental and cultural importance. In addition to ‘Beach Nourishment Scenario’, artificial beaches could be created, similar to Cullen Bay. There are natural head lands at these areas to contain the sand although a groyne structure (unsightly) would probably be needed at the eastern end. This approach will also provide the public with a recreational destination. ‘Managing Surface, Stormwater and Groundwater Flows’, scenarios for minimizing the impacts of surface runoff due to infrastructure near the beach such as large car parks and inadequate groundwater and stormwater drainage systems. This can be achieved through perhaps extending the release point away from the cliffs and toward the sea by appropriate lengths. Clearly this scenario will need to be accompanied by one of the other scenarios mentioned above. All management options will also need to take into considerations the impact of climate change on the coast.

The research was presented in and published by the Second International Conference on Geoinformatics Technology for Natural Disaster Management and Rehabilitation, pages 21–26. This was held by the Asian Institute of Technology (AIT) at Bangkok, Thailand during 2008. A consultancy report dealing the issues, the process of investigation and the outcomes were presented to the Darwin City Council in Australia (Jones et al. 2008).

5.6 Suitability Science and Management: A Conclusion

One of the most useful applications of GIS for planning and management in the land use/cover suitability mapping and analysis. Broadly defined, suitability analysis aims to identify the most appropriate spatial pattern for future land uses according to specific requirements, preferences, or predictors of some activity.

The GIS-based suitability analysis has been applied in a wide variety of situations including ecological approaches for defining land suitability/habitants for animal and plant species, suitability of land for agricultural activities and landscape evaluation and planning. The role of GIS in suitability analysis has evolved along with the changing perspectives of planning from scientific approaches through the political process-oriented perspectives to a focus on communication to collective-design approaches. It is evident that the changing nature of planning has been associated with increased involvement of non-experts (public, interest groups, communities, stakeholders, nongovernmental organizations, etc.) in the planning and decision making processes. The evolution of planning has been paralleled by the increasing accessibility of GIS technology. GIS systems have evolved from expert based decision making tool a to collaborative user friendly technology where all inputs are considered whether they be from professional or local bodies. This trend has stimulated a movement in the GIS community towards using the technology to increase the democratization of planning process via public participation.

My research in this field started with supervising student projects a process which offered me the opportunity to learn about the planning process and use GIS to indentify suitable landfill sites, wind farms, reservoirs and water pipelines in the UK, Malaysia and the Caribbean.

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Chapter 6
Sustainable Development Science and Management

6.1 Introduction

Several major external (global climate change, global economics and geopolitics) and internal (regional governments' national land policies, population growth and illegal settlements) factors are impacting negatively on developing nations and could become hindering factors for achieving sustainable development in the future. If the developing nations are to manage the environmental, social and economic effects of these changes, they need to develop appropriate mitigation strategies to address their likely impacts and consequences.

In my view, realising sustainable development will require a holistic approach and relevant information on different fundamental features of the environment such as water, soil, natural habitats and biological diversity are essential. This approach requires collecting reliable data, developing scientific concepts with the ultimate goal of enabling future development decisions to be based on reliable information. Clearly my Geosciences and environmental background has shaped my contribution to the discipline.

My association with sustainable development science and management advanced through supervising student projects and conducting water related research in Jordan. My works with the National Agency for the Protection of the Environment in Tunisia as well as colleagues from Iraq lead to research on the sustainable management of water resources. In Iraq, I focused on water resources management, sustainable food production as well as using Geoinformatics for realising sustainable development. My work in Malaysia included developing scenarios to sustainably manage reservoirs through deforestation and level terracing within the hydrological catchments. In the Caribbean, I worked on environmental management, information poverty and climate change as well as managing hillside developments. In Australia, I was involved with attempts to understand and manage the impacts of climate change on wetland, coastal areas as well as coral coastal coral reef habitats.

S. M. J. Baban, *Managing Geo-Based Challenges*, Environmental Science and Engineering, DOI: 10.1007/978-3-319-07380-4_6,

6.2 General Enabling Research

Overall, my experience indicates that planning and sustainable decision making in general and in developing nations in particular are seriously compromised due to the lack of data, meta-data, the effective use of new technology and the failure to understand the influencing factors and other processes on a regional basis.

In order to understand the extent of using the new technologies of Remote Sensing, GIS and WWW in Geo-science Education, I have initiated a survey in the UK, the results were as expected the more progressive and larger universities in the large cites came on the top. This research was published the *Surveying and Land Information Science Journal* (Baban 2002a). Another examination for Geoinformatics education in the Caribbean was conducted as a market research for developing a Mater's level degree in Geoinformatics and to identify potential users for the technology. The research published in the *Asian J. Geoinformatics during 2004* (Ramlal et al. 2004). Data collection and extracting relevant information is often conducted through the processes of Sampling, data collection and analysis. Unfortunately, some practices in this regard are not rigorous and scientifically satisfying. Hence, I have with the assistance of a colleague developed and extensive document providing theoretical and practical examples and hints to guide these essential processes. This effort was published as chapter in a book during 2009 (Baban and Lauckner 2009).

6.2.1 Information Poverty

The lack of effective and reliable information base for decision making is termed *information poverty.* I became interested in developing a way forward to deal with information poverty issues and decision making during my work on several projects in Jordan (Fig. 6.1) and after my arrival in the Caribbean region. This research advanced and evaluated the concept that a way forward to endure *information poverty* is to utilise available, and reliable cutting edge technology such as satellite remote sensing, global positioning systems and geographic information systems to originate, develop, supplement, manage and analyse the necessary datasets. Furthermore, it was concluded that this technology can be used to develop plausible scenarios, which doesn't require detailed data sets and extensive knowledge, to evaluate the necessary mitigation strategies for addressing possible impacts on the region. Aspects of this work were presented (Baban 2002b) and published in regional conference during 2002 dealt with *Developing A Research Agenda for the Caribbean Food System to Respond to Global Climate Change* (Baban 2002c), and in another conference entitled "*From Turbulence to Tourism: Tobago in Transition*, *organised jointly by the University of the West Indies and Tobago House of Assembly* during 2004 (Baban 2004a). The extensive version was published in the *West Indian Journal of Engineering* (Baban et al. 2004).

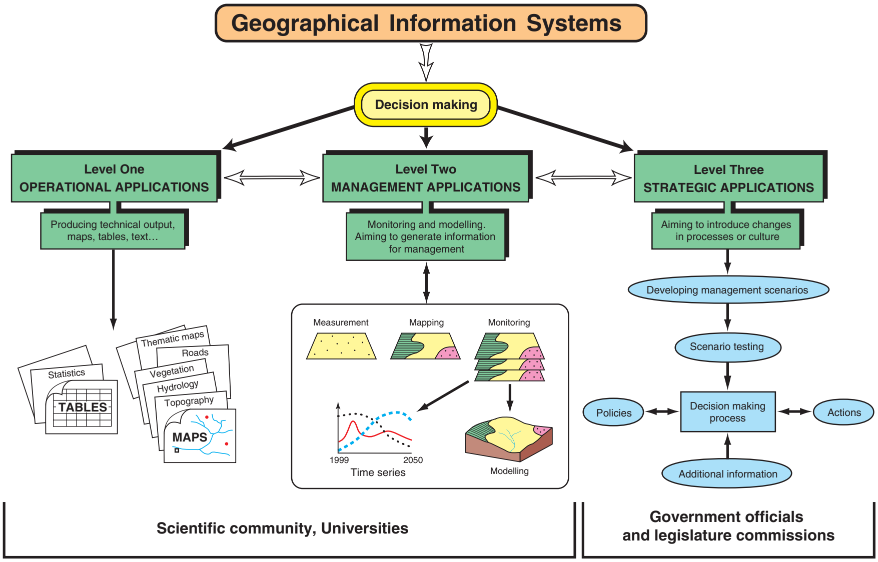

Fig. 6.1 GIS usage for decision making at different levels

6.2.2 Metadata

Metadata is data about data to be used in an application and captures the basic characteristics of data or information resource. It represents the *who, what, when, where, why* and *how* of the resource. Geospatial metadata commonly document geographic digital data such as Geographic Information System (GIS) files, geospatial databases, and earth imagery. In the digital age where datasets can be obtained from different sources, Metadata is essential for evaluating the acquired datasets as well as the accuracy of the final product, being a map or another digital dataset.

I became involved in dealing with issues related to Metadata for Secondary Geo-Based Data Sets in Developing Countries. This work was presented (Baban et al. 2006a) and published in the proceedings of the *Urban and Regional Information Systems Association Conference, URISA's 2006 Caribbean GIS.* It was held in the Bahamas during 2006 (Baban et al. 2006b).

6.3 Sustainable Development Science and Management in the UK

6.3.1 Environmental Management

In the UK, the concern during the 1990s for losing natural and semi-natural habitats was mounting and Remote sensing due to the availability of suitable spatial, spectral and temporal resolutions presented an innovative tool for mapping, analyzing and attempting to minimize the damage through various strategies. Through a Post-graduate project at Coventry University, I became involved in projects dealing with managing the damage to natural and semi-natural habitats Warwickshire. The research was presented the *Remote sensing Society Students Meeting* at University of Durham. UK during 1996 (Moran et al. 1996). Then the team focused on the attempts to identify habitat change using remotely sensed data. Some of the outcomes were presented in the British *Ecological Society Meeting* at University of Warwick. UK during 1997 (Moran et al. 1996) and published as part of the meetings programme (200). Then we explored the use of Geostatistics and GIS in extracting Habitat Change information from Remotely sensed data. This research was presented in the *GIS Research UK. 98* (Moran et al. 1998).

6.3.2 Water Resources Management

Sustainably managing water resources is of a critical importance for any society and worldwide. However, this is a complicated task as water resources in general including lakes and rivers are dynamic in nature and endure gradual changes over time. This fact was stated by Hutchinson in the late 1950s (Hutchinson 1957). However, an added complication since is that the slow gradual changes, in many lakes around the world, seems to have been replaced by a more rapid change and swift degradation. This is mainly due to the addition of plant nutrients, organic matter and sediment into these lakes. These additions usually combine to produce increased algal and rooted plant biomass, increased turbidity and, typically, decreased lake volumes.

In my view, the use of remotely sensed data for mapping, monitoring and ultimately managing water bodies such as rivers, lakes and estuaries are important. Hence, I became involved in a project attempting to use remotely sensed Landsat TM Imagery to sustainably manage lakes (Fig. 6.2), estuaries and rivers. I developed an interest in use of Remote Sensing and Geographical Information Systems in Developing long-term Lake Management Strategies for lakes. Literature shows that this objective usually requires a significant reduction in water column nutrient concentrations. In practice, Phosphorous (P) is the nutrient, which is usually targeted in lake management. This is because P is often the limiting nutrient relative to plant requirements and it therefore can regulate further growth. This is apparent for two reasons. First, unlike nitrogen (N) and carbon, P does not have a gaseous phase to its cycle so that the atmosphere is not a source of P in the lake. Secondly, P can often be permanently bound with metals such as iron or calcium in lake sediments. Therefore, when external loading has been decreased, internal loading from sediments can be managed by adding salts of these elements to the sediments (Cooke et al. 1993). Other factors affecting algal biomass include flushing rate, light availability, pH, and zooplankton grazing. These factors can be manipulated as part of a management plan, though significant nutrient reduction remains as the central part of most plans for long-term improvement of problems of excessive algae. My research approach was based on calculating and mapping water quality

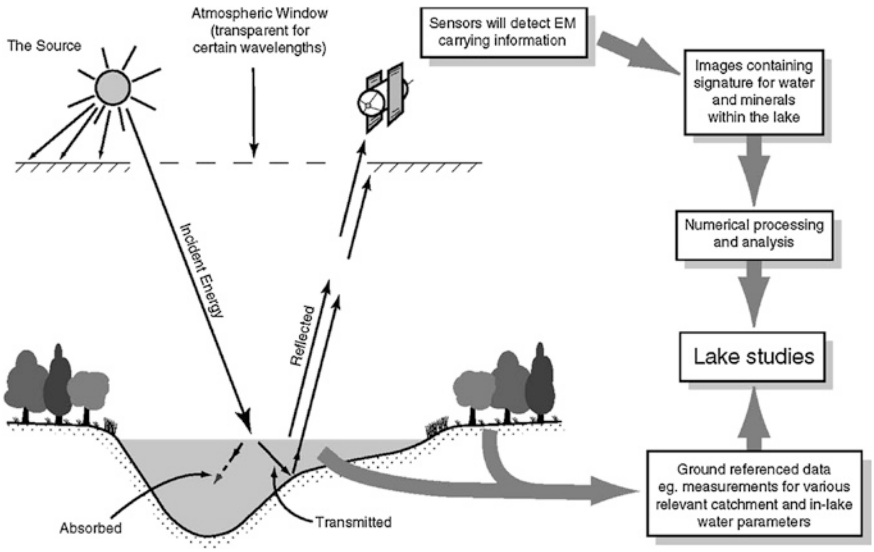

Fig. 6.2 An approach for using remotely sensed data for mapping, monitoring and sustainably managing lakes

parameters and associating their spatial and temporal distributions to natural and anthropogenic factors (Fig. 6.2). This has proven to a practical and useful tool for ecologists and it was published as chapter in a book entitled *The Ecological Basis for the Management of Lakes and Reservoirs* (Baban 1999a).

As a follow up, I became interested in developing a remotely sensed approach for categorising lakes based on their trophic status. Water quality in lakes is often described in terms of trophic state where the trophic state of a lake refers to its degree of nutrient enrichment, generally nitrogen and phosphorous (Hasler 1947; Witzing and Whitehurst 1981). A lake with extreme nuisance algal blooms or a lake narrowed with aquatic weeds is said to be eutrophic (nutrient rich). A lake with very clear water is described as being oligotrophic (low nutrient, high oxygen) (Lillesand and Kiefer 1994). The boundary between oligotrophy and eutrophy is necessarily arbitrary, and the values chosen will also change with respect to the variables used in making the classification. Some lakes may be considered oligotrophic by one criterion and eutrophic by another. This problem can be circumvented by classifying lakes that show characteristics of oligotrophy and eutrophy as being mesotrophic. All trophic classifications are based on the division of the trophic continuum, defined as a series of classes termed trophic state. The conventional classification divides the continuum subjectively into three classes: oligotrophic, mesotrophic and eutrophic. The trophic state index *(TSI)* divides the continuum objectively into a quantifiable range of values.

My research approach for developing lake trophic indices has focused on mapping the consequences of eutrophication and an increase in productivity as these will be associated with a change in the optical properties of the water mass, hence using remotely sensed data for extract this information. This research builds upon previous work which explained and illustrated the details of how TM data have been used to

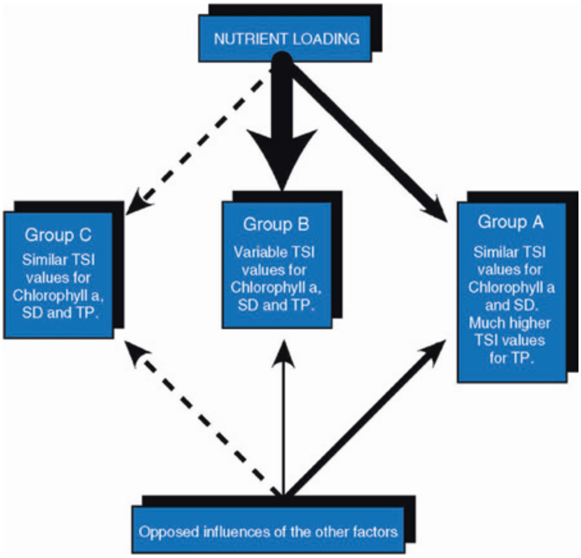

Fig. 6.3 A conceptual framework for classifying the lakes using TSI principles (Baban 1996)

estimate water quality parameters in the Broads (Baban 1993, 1994). The objective of the project were to test the sufficiency of information extracted from Landsat Thematic Mapper (TM) imagery (which I had developed in an earlier study, Baban (1993) and the Carlson *TSI* (a) in establishing trophic status estimation models for the Norfolk Broads, and (b) employing these models in an attempt to classify the Broads trophically. The results showed that the Carlson *TSI,* in combination with Landsat TM imagery, has succeeded in providing a considerable body of information for the 26 Broads included in the analysis (Figs. 6.3 and 6.4). By using instantaneous information and numerically comparable classes this is a very effective combination for comparing different parameters in various Broads at the same time, as well as:

(a) identifying the influence of the sediment coefficient and flushing rate on delaying/stopping the eutrophication processes. This information could be employed within restoration efforts to reduce the influence of external total phosphorous loading on the eutrophication of other Broads;
(b) establishing a methodology for checking the ecological balance in the Broads. This could be employed to provide, update, examine and compare the progress of various reclamation programmes in the Broads (Fig. 6.4).

This study illustrates the successful role of remote sensing in an ecological context which is particularly valuable when there are no ground reference data available at the same date as the Landsat imagery. Typical true values could be used in correlation with the Landsat data to update information and to extrapolate it to other areas within the image. Although the accuracy may not be very high, it is considered sufficient for many purposes as well as being a cost effective practice. This research was published in the *Hydrological Sciences Journal* (Baban 1996).

Later on I reflect that Dillon and Rigler (1974) advocated the use of a regression function that can be used to predict the average summer chlorophyll concentration

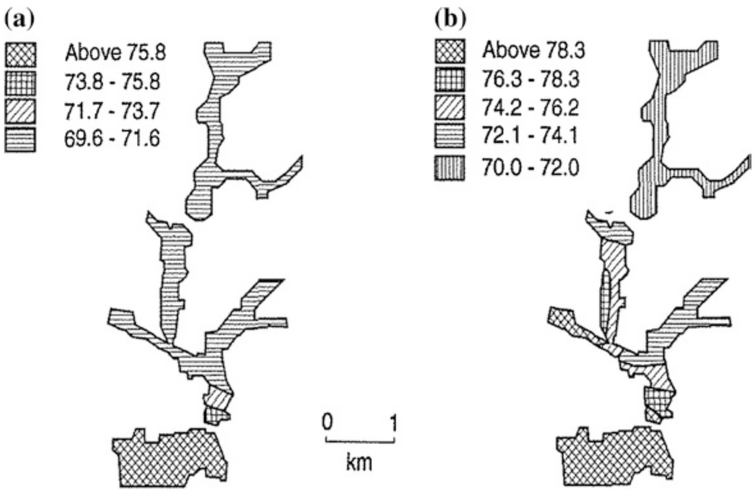

Fig. 6.4 Mapping the Trinity broads based on TSI principles (Baban 1996)

from a single measurement of phosphorous concentration at spring overturn. Building on this premise, the technique in this study offers the potential for detecting short term blooms of the toxic blue green algae which are common in these water bodies. The latest blooms in the UK were during August and September 1990, September 1991 and September 1992, covering many water bodies throughout the country. These blooms led to a great deal of concern from the public since it was reported frequently that the toxic blooms could blister human skin and cause sickness, diarrhoea and fever if water were swallowed, and that they could be fatal for animals. Although it may not be possible to control fully the formation of the blooms, reducing phosphorous availability has been suggested as one method of attempting to do so (NRA 1990). Combining this information with the findings of this study indicates that the application of remote sensing techniques could be used effectively by the Environment Agency and other water authorities to control this problem.

As a follow on from the previous research, I wanted to examine the possibility of using remotely sensed data for Environmental Monitoring of Estuaries. More specifically to establish Environmental Indicators in Breydon Water Estuary, UK and to use this information to monitor this complex and dynamic environment. Once, I had sufficient ground reference data, I proceed with the research. In this work, Satellite images of Breydon Water Estuary, U.K., were enhanced to estimate and map water quality parameters assisted by ground referenced data. The spatial and temporal distribution of suspended solids, turbidity, temperature, salinity, chlorophyll *a* and total phosphorus were estimated and mapped with various degrees of success in Breydon Water Estuary using satellite (Landsat Thematic Mapper) imagery. All the indicators exhibit a similar spatial pattern within the estuary. High values are found at both the saltwater and freshwater ends of the estuary, and low values are found in the mixing zone (Figs. 6.5, 6.6 and 6.7). The pattern is thought to be due to the influence of suspended solids and turbidity

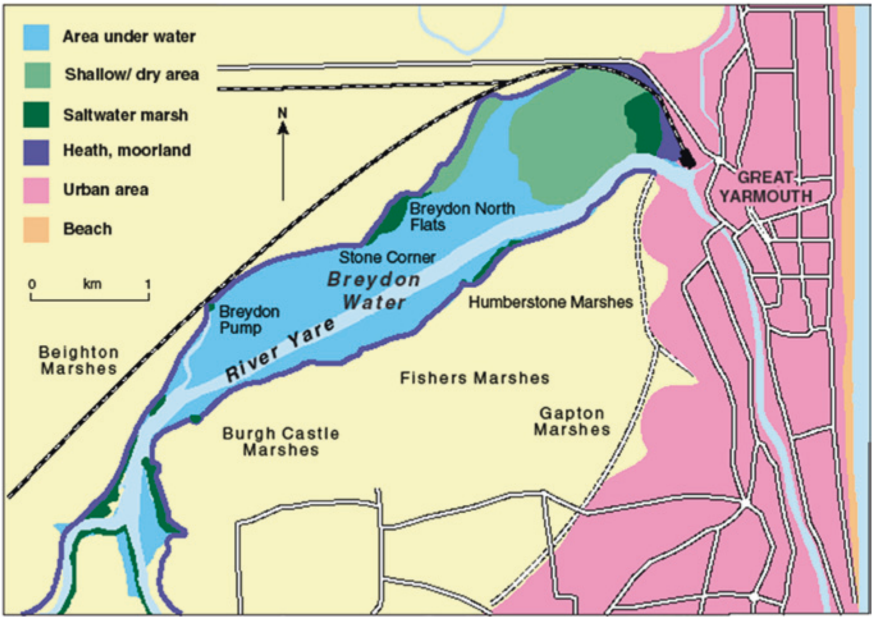

Fig. 6.5 Ground-referenced map of Breydon Water Estuary, UK. Compiled from field observations, aerial photographs and available maps

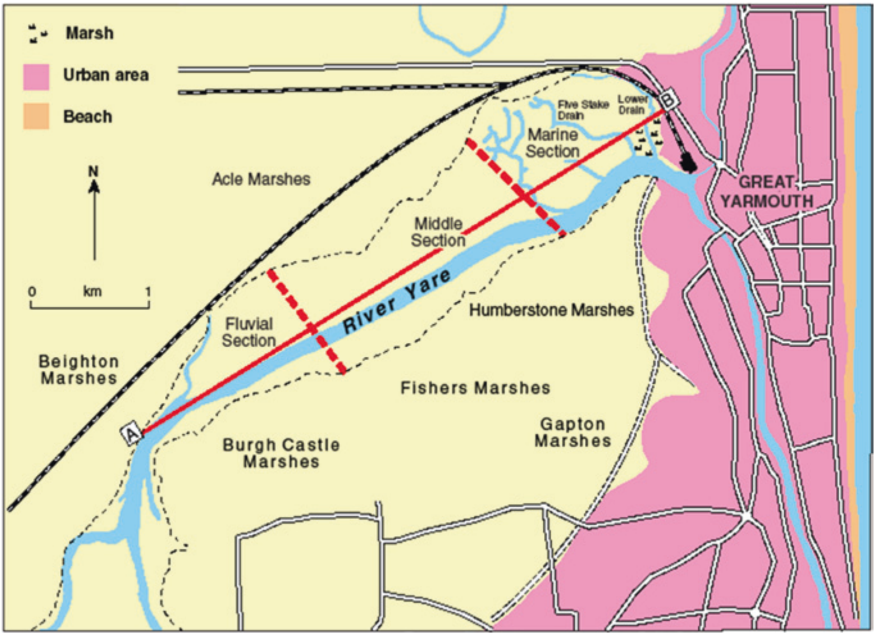

Fig. 6.6 Breydon Water Estuary, UK showing the Marine, Middle and Fluvial sections

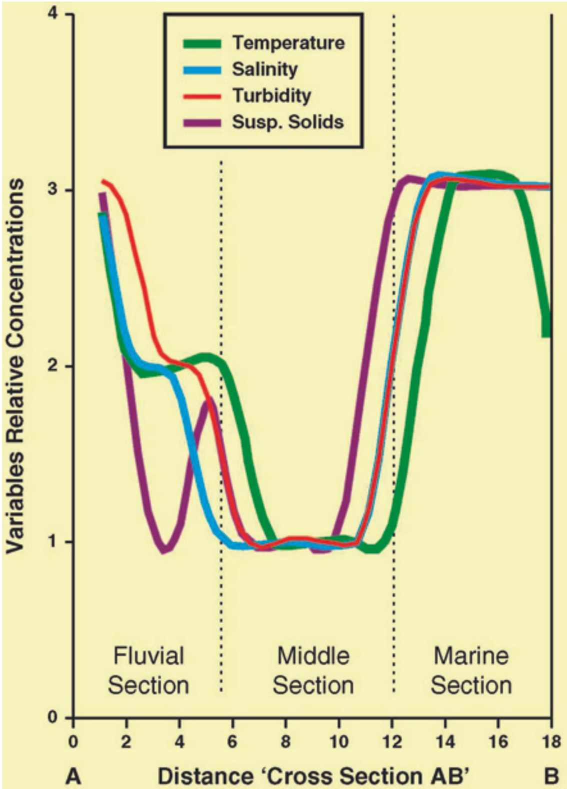

Fig. 6.7 Correlations among various environmental indicators in Breydon water estuary

on the optical characteristics of water in this environment. The distribution of suspended solids and turbidity are influenced by the flood–ebb intervals, the sedimentation processes and the internal topography of the estuary. All of the predicted values are consistent with those reported in the literature. This research was published in the *Estuarine, Coastal and Shelf Science Journal* (Baban 1997a).

6.4 Sustainable Development Science and Management in the Middle East

6.4.1 Jordan

Land degradation and the scarcity of water resources are critical factors hindering sustainable development in nations such as Jordan which are located in arid and semi-arid regions. As these factors seem to have a direct impact on the economic development and prosperity of the country. Furthermore, some will argue that these can also influence the political stability of the region.

6.4.2 Environmental Management

Desertification and water shortage problems are more severe in the arid to semi arid areas in the region. These areas are expanding and causing environmental degradation at an alarming rate. This is not only due to climatic conditions; prolonged droughts might lead to environmental degradation and will convert an area into desert. Nevertheless, the vegetation cover can revive quickly when favourable climatic conditions return, provided the soil has not deteriorated thereby losing its productive capacity. However, this process can be curtailed by heavy human impact which originates due to socio-economic and cultural factors. This is further intensified by depletion and deterioration of ground water, industrialization and agricultural expansion. In addition, geopolitics plays an important role in this region, as water resources are not restricted by international borders and almost all upstream countries have started over-ambitious development programs to attain self-sufficiency in agricultural products (Clark 1991). This combination of climate and human impact seems to be responsible for water shortages and desertification problems.

My research sought to explore the potential for developing a methodology, based on an integrated approach taking into consideration local environmental and socio-economic factors, for the analysis and management of transboundary water resources using ground surveyed (referenced) data, Remote Sensing and GIS. The research developed a holistic plan to manage desertification and water shortage problems in the Badia region, Jordan using Remote sensing and GIS. Exploring the potential of Remote sensing for providing the necessary spatial and temporal data at various scales and enabling the study area to be examined as an integrated system rather than as individual entities. Furthermore, the plan explored the facilities provided by GIS to integrate, combine, analyse and model the data. Overall the plan offered decision makers an opportunity to map land use/cover types on a regular basis, determine the rates of change, identify the main causes leading to long-term degradation and identify, for example, vegetation communities at risk. In addition to simulating and visualizing various management actions to anticipate the consequences of implementing each action over different periods of time objectively; ultimately enabling them to optimise management decisions. Aspects of this research was presented in an international workshop dealing with *the Water Resources and Environment in the Badia Region which was held in AL al-Bayt University in Jordan during 1999* (Baban 1999b). Later a more extensive version was published in the premier desertification publication, *Desertification Control Bulletin,* which is supported by the United Nations Environmental Programme (Baban 2000a). The aspects of the research dealing with using GIS, Remote Sensing and DRASTIC for mapping Groundwater Vulnerability in the Basaltic Aquifers of the Azraq Basin of Jordan was published in the Journal of *Applied Geography* (Al-Adamat et al. 2003).

I was also involved in research developing information on the expansion agriculture activities in the Badia region from 1992 to 2000. The outcomes showed a significant increase in agriculture within the desert environment (Figs. 6.8 and 6.9). I also examined the climate and water resources which included an introduction on the climate and water shortages in the region, rainfall characteristics, spatial distribution and statistics,

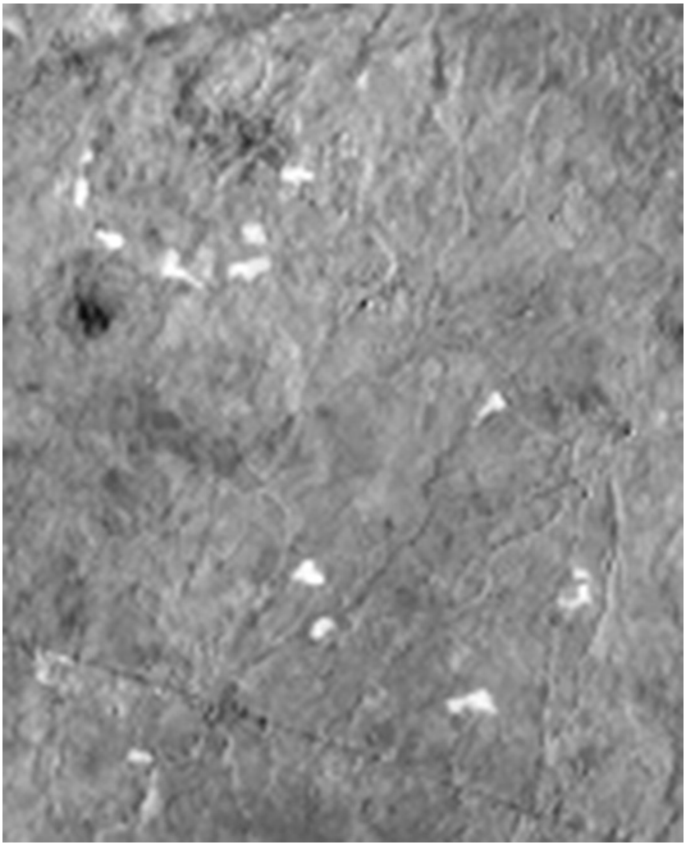

Fig. 6.8 Agriculture activities in the Badia Region, Jordan during 1992 (Al-Adamat et al. 2004)

evaporation, runoff, wind speed and direction as well as hydrogeology including an examination of groundwater aquifers systems. This work was published as a chapter in a book dealing with water scarcity in the Badia region (Al-Ansari and Baban 2001).

6.4.3 Sustainable Development

Through my collaboration with the Badia Research and Development Programme, I became involved with a project that was focused on developing a research agenda to minimise Water shortage problems in the Badia region using remote sensing and GIS. The combination of climate and human impact appears to be responsible for water shortages in the region. Approaches to these problems are usually packaged under *Water Development Schemes,* examples include;

(i) Expanding irrigated land schemes, the Aral Sea Basin Development project in the former USSR, which was the world's fourth largest freshwater lake, occupying an area of 3.5 million km^2 was destroyed by expanding irrigated areas

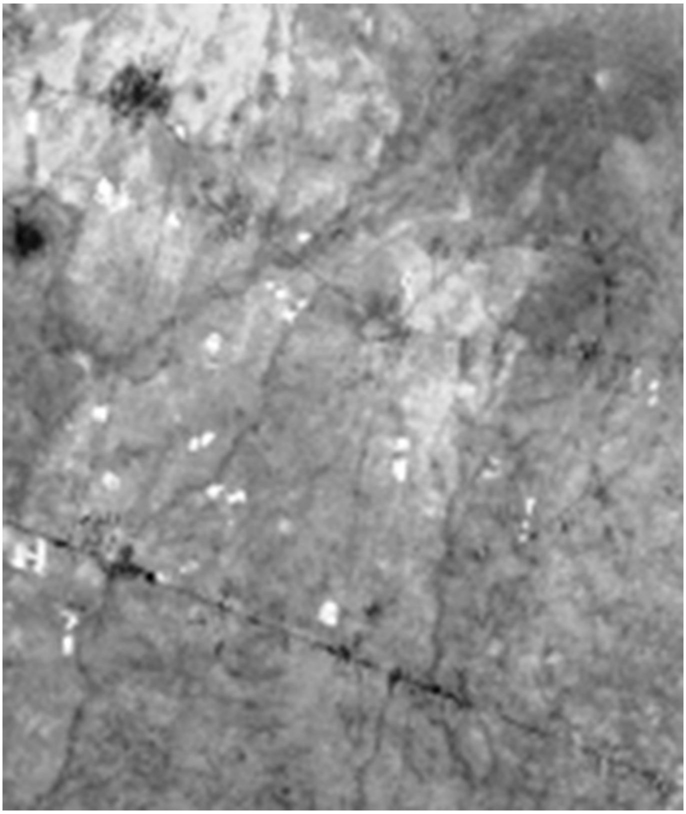

Fig. 6.9 Agriculture activities in the Badia Region, Jordan during 2000 (Al-Adamat et al. 2004)

by a factor of six over 40 years. This expansion was sustained by diverting up to 80 % of the water from rivers supplying this lake. As a result, the water level fell by 13 m, the salinity tripled, the fish catch, once 25,000 tonnes a year, was reduced to zero and the surrounding areas have turned into waterlogged soils and salt marshes (Clark 1991).

(ii) Livestock development and rangeland schemes, similarly, an area for pastoral development was established based on a network of boreholes in the Republic of Niger. Unrestricted access was given to the boreholes. The outcome was the destruction of the grazing resource in a radius of 20–30 km around each borehole in two to three seasons. In the peak of the 1970–1973 drought, large numbers of livestock died around the boreholes, not of thirst, but of hunger (Le Houe′rou 1994).

(iii) Oasis and irrigated schemes, such a scheme was set-up in Mali. The majority of the areas where these schemes are in operation are surrounded by degraded land. This is because the farmers tend to use the adjacent dry land as much as possible for rain-fed farming, heavy continuous grazing, indiscriminate firewood collection and other questionable management practices (Le Houe′rou 1976). Often the money earned from irrigated farming is reinvested into more

> livestock, which are allowed unlimited free grazing within a radius of 5–6 km for small stock and 20–30 km for cattle. A study based on 1:50,000 scale aerial photographs taken in 1952 and 1975 for an irrigated scheme project in Mali indicated that heavily degraded land has increased from 4 to 26 % of the study area whilst the cropped land expanded from 2.8 to 5.5 % (Le Houe′rou 1998).

This project proposed developing a regional database containing all relevant physical/environmental, demographic and socio-economic data which needed to be established within the framework of a GIS. The project focus was developed with reference to needs identified by politicians, government senior scientists and advisers and academics responsible for, and dealing with, the environment, water and population issues in the Badia Region. The outcomes from the project can be used to promote applied environmental and hydrological programmes in higher education institutions in the Badia Region. Consequently, this project will have a significant impact on the formulation of a comprehensive water policy for the Badia Region and will facilitate integrated planning. Aspects of this research were presented in the *International Groundwater Conference, Groundwater India 88*, which was held in India during 2008 (Baban 2008a). The aspects of the research dealing with the climate and water resources was developed with AL al-Bayt University in Jordan and published as chapter in a book (AL-Ansari and Baban 2001). Furthermore, a holistic Approach to Study Water Shortages in the Badia Region in Jordan Using Remote Sensing and GIS was presented in *Eco-Summit 2000, which was held in* Halifax, Canada (Baban 2000b). Some of this research was supported by a grant from the *Department of International Development, UK* under a project entitled: Protecting Water Resources in the Badia Region, Jordan. Another project I worked on collaboratively with the Jordan Badia Research and Development programme dealt with promoting sustainable development and environmental protection in the Jordanian Badia region. The Bedu have lived for centuries in harmony with the environment in the Middle Eastern desert known as the Badia region. The Bedu were practically self-sufficient, the sale of their animals and animal products provided them with some income for their additional food needs. Their cash requirements however were met by transporting goods across the desert, and renting or selling camels to town dwellers. The Bedu were completely reliant on wild natural grass for animal feed, such that the total number of animals kept at any one time depended upon the seasonal situation. The Bedu have survived the hostile environment by migrating vast distances to find pastures and water sources for their herds of camels, sheep and goats in the Badia region, which is now known as parts of Jordan, Syria, Iraq and Saudi Arabia (Al-Oun 2001). The geographical division of Arabia into small states resulted in the Bedu being separated from their land and other Bedu population. (Al-Rabia 1974). The restrictions on movement have since played a key role in the decline of pastoral nomadism in the region and sealing off major towns, water sources and good pasturage. Consequently, the pressure on the environment and its resources has intensified and reached breaking point in many parts of the Badia. Accordingly, a strategy was formulated to achieve a difficult balancing act between environmental protection and development. The strategy was realized through establishing the Jordan Badia Research and Development Programme (BRDP) during 1992. BRDP was given a mandate to search for a complete understanding of the human and physical resources base and to assist in achieving sustainable development in the Badia region. The positive impact of the BRDP on the Badia in Jordan is evident in the number of completed Ph.D., M.Sc. research degrees, B.Sc. degrees, completed research projects, and various environmental education programmes. I recommended that the aspiration should be to link these programs throughout the Badia region in the future. This research was published in the *Journal of Sustainable Development* (Baban et al. 2003).

6.5 Tunisia

6.5.1 Environmental Management

I became involved in collaboration with the National Agency for the Protection of the Environment (ANPE); Sousse, Tunisia during the late 1990s and developed an interest in Environmental Protection and Sustainable Development in Tunisia. Tunisia, like other African countries, suffers from environmental problems such as high rates of soil erosion, desertification and salinisation which in part may be caused by the climate due to its geographical location. These problems are generally compounded by the destruction of natural protective vegetation cover, overgrazing and agricultural expansion. All of these contribute to a reduction in biological diversity and to high rates of erosion, which is a widespread problem in Tunisia, Morocco and Algeria (Woodward 1995; Lahlou 1996, Woodward and Foster 1997). Accelerated soil erosion will often result in the loss of valuable agricultural land and increased suspended sediment concentrations and loads in rivers. These in turn will lead to rapid reservoir sedimentation, decreased storage capacity and also give rise to high rates of evaporation from impounded water bodies (Belkheiri 1987; Lahlou 1996). In Tunisia, water storage schemes provide some 66 % of the available water resources and water demand for domestic, agricultural and industrial purposes is increasing continuously (Bouzaiane 1991). Therefore storage loss to sedimentation is an urgent problem and could represent a threat to the pace of future agricultural and industrial development. As a response to this demand, efforts are made to increase the quantity of usable surface water by building more reservoirs (National Report 1995).

I also developed an Integrated Approach to Minimise Natural Habitat Loss in Tunisia, this work was presented and published as proceedings of an international conference focused on satellite based observations as tool for studying the Mediterranean Basin, it was held in Tunisia (Baban 1998).

6.6 Sustainable Development

Tunisia in the 1980s and 1990s experienced a significant economic development and urbanization. I was interested in examining the impacts of the development process on the environmental degradation of water resources and biological

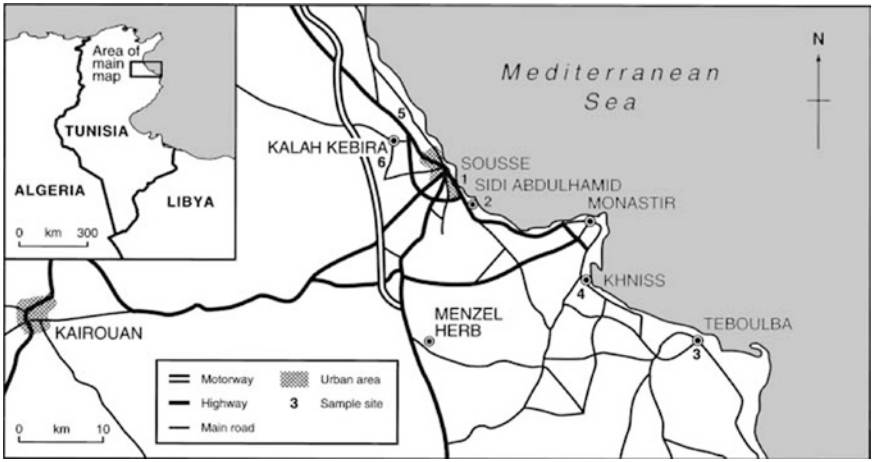

Fig. 6.10 Sites for environmental programmes around Sousse and Monastir (Baban et al. 1999)

diversity. My study reviewed the background to environmental protection and attempted to reflect upon the way a sustainable development package has been formulated and implemented. The research showed that Tunisia has realised since the 1980s that environmental protection is the key to sustainable development. Accordingly, a set of aims and objectives have been formulated to achieve a difficult balancing act between environmental protection and development. The process was started by establishing necessary infrastructure, framing environmental legislation, providing financial incentives for business and industry to invest in environmental protection and to encourage polluters to dispose of waste in an environmentally friendly way and finally developing environmental education programs. The impact of the environmental protection package (legislation, financial incentives and environmental education) on Tunisia‘s environment was assessed through observing sites, near Sousse and Monastir, with various environmental problems on two field visits during 1996 and 1998. Several successful realisation of essential parts of Tunisia‘s environmental protection program were witnessed. The following is an example dealing with land reclamation in the Teboulba-Al Fathileen Quarries (Site number 3, Fig. 6.10). Here a number of old and new quarry sites are found, most of which have near vertical walls and floor depths in the vicinity of the ground water table in the area, these large cavities were used improperly. Therefore it is important to develop some environmental protection and reclamation programme for these quarries. A quarry reclamation strategy need to allow for all the possible alternatives of after-uses and site conditions. Literature shows that the basis of all landscape reclamation schemes consists of two parts; *Engineering reclamation which* is concerned with the creation of suitable landforms, and accounts for stability of tips and rock faces and drainage. The second part is. *Biological reclamation,* this is concerned with establishing and maintaining vegetation on the new landform, and the operational requirements of the quarry. Vegetation will play a key role in providing screens, slope stabilization

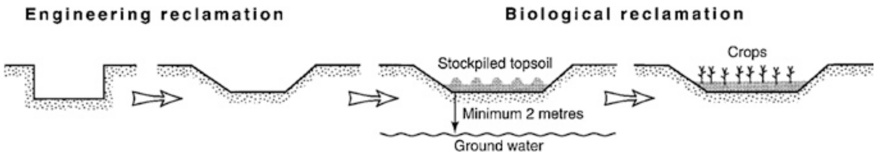

Fig. 6.11 Quarry restoration to agricultural use by using stockpiled topsoil in Al Fathileen Quarries, Teboulba (Baban et al. 1999)

and erosion control, soil improvement, visual improvement and, finally, providing some satisfactory after-use (Coppin1981). The task of the ecologist will be to bring these two components, together taking into consideration site specific characteristics for a particular quarry. Our indestigation indicated that the environmental instructions dealing with exploiting quarries in Tunisia promote rehabilitating sites through restoration by using stockpiled topsoil. The procedure an investor should follow once finished with a site (Fig. 6.11). An additional positive outcome is creating badly needed agricultural land and promoting agricultural production. Evidence for all of these stages of the programme was found on this site during the 1996 and 1998 visits (Fig. 6.11). This work was published in the *Journal of Sustainable Development* (Baban et al. 1999).

6.6.1 Environmental Management

In the Middle East water resources are limited, and are currently decreasing, whilst the demand for water consumption is increasing for reasons such as the expanding industrialisation and population growth. This combination makes the distribution of this limited resource very difficult and potentially explosive. In fact an investigation by the centre for strategic and International Studies in Washington, DC, concluded that the situation is likely to become so acute that, in the near future, water -not oil- will be the dominant resource of the Middle East (Star and Stoll 1988). This prediction is most likely to be realised for three major reasons. First, for geopolitical reasons; since water resources are not restricted by international boundaries. An examination of the recent history of the region indicates that the race to develop water resources has already started. Many upstream countries in the Middle East have drawn up plans to divert shared river and aquifer water supplies to fill reservoirs and irrigation systems in order to increase agricultural production. To date many of these plans are being implemented. Secondly, natural problems hinder the full use of the available water resources in the region. For example most of the lakes and reservoirs in the Maghreb States of North Africa suffer from sedimentation problems. Consequently the increase in water demand over time will be associated with a diminished storage capacity (Bouzaiane 1991). The third problem is the weaknesses of the decision-makers. Some managers may have a poor general knowledge of the problem due to their appointment for political reasons (Perera and Tateishi 1995). Consequently and for obvious reasons, the decision making process becomes subjective rather than objective.

Water resources in the Middle East, are therefore likely to dominate the headlines for some time to come. In order to actively promote political and social stability, minimise the damage and strike a balance between environmental and economic concerns, water managers and decision makers should use every aid available to them as they attempt to mange their limited water resources. They will also need the ability to reflect upon, and anticipate, the consequences of their decisions. A logical way of making informed and objective decisions is to base them upon all available information and use an objective approach in arriving at appropriate decisions.

My research examined the applicability of Satellite Remote Sensing (SRS) within a Geographical Information System (GIS) framework as a water management tool, focusing on Iraq as a case study was examined. The relevance and the possible success of a range of applications were examined. Based on the outcome of these assessments a hydrological GIS appraisal and management system was proposed. This management system used SRS as an information source and GIS as an analytical tool within the management system. The system enabled decision makers to extrapolate, predict, update, plan, evaluate, compare, simulate and visualise various management actions and to anticipate the consequences of implementing each action over different periods of time in an objective manner, ultimately enabling them to optimise management decisions. This research was presented in an international conference and was published as refereed chapter in a book (Baban 1997b).

I applied the same principles and examined the applicability of Geoinformatics as a water resources management tool in Southern Kurdistan and the relevance and the potential success of a range of applications, including water supply, hydrological catchment management, and managing sedimentation in reservoirs, floods and agriculture. Based on the outcome of these assessments a Geoinformatics based hydrological management system is proposed. This management system will assist the decision makers to select sustainable management options. Different aspects of the research were published as two journal papers (Baban 2005, 2006).

6.6.2 Sustainable Development

Having returned to the Kurdistan region and observed the ongoing rapid development and urbanization as well as the heavy reliance on oil and gas as the main pillars for the economy, I found it necessary to promote the principles of sustainable development. Hence, I became involved with dealt with examining the possibility of achieving sustainable development in Southern Kurdistan Using Geoinformatics. Southern Kurdistan is experiencing a rapid rate of development, which is often associated with increased industrialization, population growth, economic development and urbanization. These events generally lead to continuous degradation of the environment and natural resources i.e. water, soil, air, natural habitats and biological diversity. These in turn, if not managed, could eventually slow down and threaten the pace of economic development. Consequently, there is a real need to understand and attempt to manage these events. The research argued that the specific conditions in southern Kurdistan, the nature and unavailability of reliable information for decision making necessitates the use of Geoinformatics as an effective tool to sensibly utilise and conserve the environment and natural resources whilst furthering the development process.

I developed an interest in planning for achieving sustainable food production and for sustainably managing water resources in the region through a examining all available data and consultative process involving all stakeholders and experts in the region. The result was a Road Map which was presented in an international meeting in London (Baban 2012) and in the *Water Iraq Summit* which was held in Turkey during 2013 (Baban 2013a). Some of the aspects were also presented in *the third World Kurdish Scientific Congress* which was held in Stockholm, Sweden (Baban 2013b) and in the *International Cooperation Platform, 4*th *Bosphorus Sumit which was held in Turkey* (Baban 2013c). Finally an extended version focusing achieving Sustainable Food Production and Security in the Kurdistan Region, Iraq was published as chapter in a book (Baban 2013d).

Recently, my Ministry team started a process for developing a Developing a 5 Year Strategic plan for the Ministry of Agriculture and Water Resources, Kurdistan regional Government, Iraq. This involved, as a consultative process, presenting at the regional conferences for the provinces to explain the vision and the realistic parameters for developing the plan (Baban 2013e, 2013f) as well as some national gathering such as the MEED conference in Erbil, Iraq (Baban 2013g).

6.7 Sustainable Development Science and Management in Malaysia

6.7.1 Environmental Management

In tropical regions, the removal of natural vegetation and deforestation due to improper land clearance to accommodate development needs associated by heavy rainfall patterns often lead to significant sedimentation problems particularly in the lakes and reservoirs. A study by Thapa (1998) showed that the extent of deforestation in all eight countries in South East Asia is significant, which ranged from 8.4 to 41.2 % between 1965 and 1988 with Malaysia losing about 20 % of its forest cover. Deforestation often leads to increases in sediment in the rivers downstream through increased overland flow. In fact, a study showed that the complete removal of forest trees can increase sediment load to about 53 times above the level of the undisturbed forest (Anderson and Spenser 1991). Therefore, when

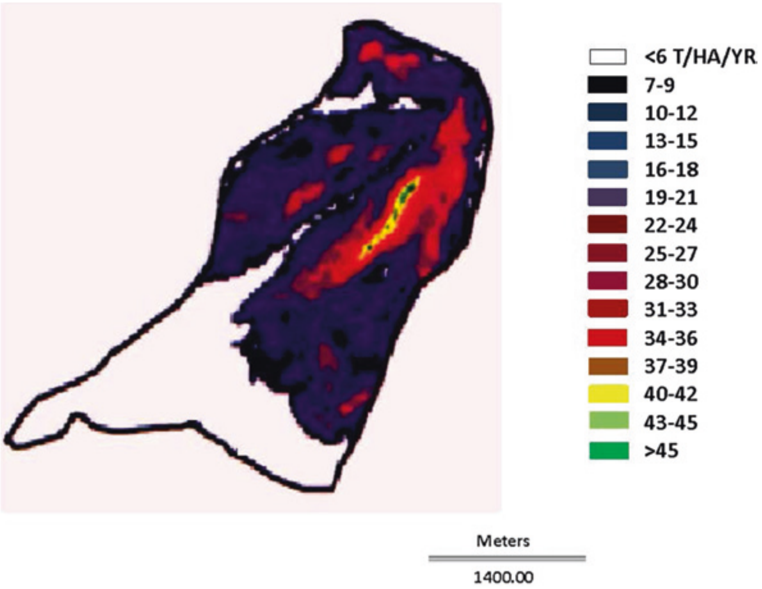

Fig. 6.12 The outcome from applying the 50 % deforestation with level terraced scenario to the Ulu Melaka catchment (Baban et al. 2003)

planning reservoir sites, particular attention should be given to managing upstream soil erosion and downstream sedimentation. Based on my previous work, I became involved with modeling hydrological catchment management scenarios to manage lake/ reservoir sedimentation problems. My research developed and simulated the impacts of the following catchment management scenarios; *status quo, assuming 50 % deforestation* and a *combination of assuming 50 % deforestation and level terracing* (Fig. 6.12). These were applied to two proposed reservoir sites in the Langkawi Island in Malaysia using the USLE formula within a GIS framework. Other scenarios, including *the construction of riparian buffer zone* were also considered based on the literature. The outcomes indicate that the *50 % deforestation scenario* could increase soil erosion by about 240 times above the level of the undisturbed forest. Whilst, managing *50 % deforestation, using levelled terracing*, could reduce the potential soil erosion to about 70 times from that of an undisturbed forest. The results also indicated that elevation and slope had a noticeable influence on soil erosion. As soil erosion increases over 240 times over 230 m and soil erosion rates in both forested and 50 % deforestation scenarios shows an increase of over 450 times by increasing the slope from 26^{o} to 37^{o}. As far as catchment management for the Langkawi Island is concerned, preserving the potential reservoir sites should be given the highest priority. These areas should be designated as reserved areas and, if development were to proceed, preventative measures, such as structural and non-structural controls should be taken into consideration. Some aspects of the research dealing with locating Reservoir Sites Using Remote Sensing and Geographical Information Systems was presented and published as of the Proceedings of the Second World Engineering Congress, Water Engineering and Geomatics which was held in Malaysia (Wan-Yusof and Baban 2002a). Some of the aspects dealing with developing Catchment Management Strategies for Sustainable Development using Geographical Information Systems (GIS) was presented and published as part of the proceedings of the 20th Conference of Asian Federation of Engineering Organisations (CAFEO), this was held in Phnom Penh, Cambodia (Wan-Yusof and Baban 2002b). An extended version of both aspects was published in the *Asian Journal of Geoinformatics*. This research in part was supported by a grant from the *MARA Institute of Technology, Malaysia* which was towards a Ph.D. Studentship for 'Developing a Catchment based Management and Planning Strategy for two sites in Malaysia, Using Remote Sensing and Geographical Information Systems'.

6.8 Sustainable Development Science and Management in the Caribbean

In the Caribbean region, the combined effects of a rapid rate of population growth, economic development and urbanization as well as facing the effects of global climate change and associated sea level rise tend to lead to continuous degradation of the environment and natural resources i.e. water, soil, air, natural habitats and biological diversity. These consequences in turn, if not managed, could eventually slow down and threaten the pace of economic development in the region. As a result, there is a real need to understand and attempt to manage these natural and man-made phenomena, deal with information poverty and climate change issues.

6.8.1 Environmental Management

I was interested in examining the possibility of attaining a balance between environmental protection and sustainable development using Geoinformatics. This research argued that the geographical makeup of the Caribbean region and the nature and unavailability of reliable environmental data necessitates the use of Geoinformatics as an effective tool to sensibly utilise and conserve land and marine resources whilst obtaining production to further the development process. An overview of the environmental problems in the region and the possible usage of Geoinformatics have been discussed. This work was published in the *West Indian Journal of Engineering* (Baban 2004a).

I was also interested in examining the issues surrounding the sensible management of the environment and how using Remotely sensed data and GIS can assist with this process. As indicated previously the Caribbean region is undergoing rapid economic development and this process often leads to environmental degradation of water, soil, air, natural habitats and biological diversity. In addition, the region is living through a number of universal events such as sea level rise and global climate change. As a result, there is a real need to understand and attempt to manage these natural and man-made phenomena. This research showed that the physical characteristics of the Caribbean region and the environmental challenges can best be managed using remotely sensed data to obtain the necessary spatial and temporal information and to use GIS for managing the data and to pin point hotspots needing attention to conserve land and marine resources. This research was presented in an international conference and published in the *Proceedings of the Urban and Regional Information Systems Association (URISA) 2001 Caribbean GIS Conference* (Baban 2001).

I was also interested in developing land degradation indicators using remotely sensed data to identify and mapping physically based indictors such as deforestation and loss of vegetation cover, flooding, soil erosion, soil deterioration (fertility decline), coastal erosion as well as agricultural and industrial pollution in the Caribbean. This research was presented and published in the *Proceedings of the Remote sensing and Photogrammterty Society 2006* (AL-Tahir and Baban 2006)

The south western coast of Tobago has some serious environmental degradation issues which captured the public's imagination. I, through a student project, proposed some management options based on data obtained through a questionnaire that targeted fishermen and tourists in the area. The analysis showed a clear degradation of the coastal environment based on the public perspective. The work was presented in a conference *organised jointly by the University of the West Indies and Tobago House of Assembly during 2004* (Sant and Baban 2004). Some aspects of the research has to manage the information poverty issues in Tobago, this work was presented in a regional conference in Tobago (Baban 2004b).

Natural habiat loss was a concern in the Caribbean; hence, my team first, through a sponsored grants from The Ministry of Planning and Development, Government of the Republic of Trinidad and Tobago developed a generalized Land Use Map for Trinidad and Tobago (Baban et al. 2006b). Then we proposed some practical approaches to Monitor and manage Natural Vegetation loss as well deforestation in the Caribbean Region, this research was presented in the Twenty-eighth Annual ESRI International User Conference, which was held in San Diego, California (Chinchamee et al. 2008) and also presented some aspects of the research in the Remote Sensing in Developing Countries Workshop in Egypt (Baban 2004c). The research in an extensive form was published in the *Tropical Biodiversity Journal* (Baban 2003a). Some of this information were used in a collaborative project with the Environmental Management Authority of Trinidad and Tobago and dealt with the biodiversioty assessment of the Northern Range, Trinidad and Tobago. This project dealt with biodiversity issues as part of the UN Millennium projects in the Caribbean region (Agard and Baban 2004).

Another research interest was understanding and managing the impacts of climate change on the development process. The Caribbean region is living through a number of events such as sea level rise and global climate change. These events often lead to environmental degradation and could threaten the sustainability of agriculture, fisheries and tourism. The states in the Caribbean have a number of common characteristics, which make them vulnerable to climate change impacts. These include; limited physical size and natural resources, high susceptibility to natural hazards, dependence on agriculture and tourism, questionable agriculture practices small local markets and high population densities concentrated on the coastal areas. This research argues the need to understand the impacts of climate change with the view to designing intervention strategies to ensure the integrity of agriculture, fisheries and tourism. The first hurdle towards achieving this objective is the shortage of reliable and compatible data sets as well the existence of 'grey areas' in the scientific knowledge regarding some of the processes involved on the national and regional scale. This hurdle can be managed by adopting Geoinformatics, which contains the necessary tools (Remote sensing, GPS/GNSS, GIS) to collect, handle and analyse the necessary data sets as well as expanding our knowledge of the processes involved at the appropriate level. I argued that our knowledge and understanding can be further enhanced by using plausible scenarios to examine alternative futures based on different intervention strategies and this can be managed within a GIS framework. The outcomes can then be used to manage the impacts of global warming and sea level rise in the region as a whole and in specific geographical locations. The second hurdle is the lack of political will and effective polices to manage the issues, identify cost effective and practical mitigation measures as well as strategies for implementing these measures. Overcoming this hurdle will require hard work however, the scientific outcomes, possible practical solutions from the first hurdle and continuous public education and action by civil society will and must win the argument so the region can have a prosperous future. This work was disseminated through a conference presentation (Baban 2002b) and at a later date it was published in an expanded form in the *Journal of Farm and Business* (Baban 2003b).

Trinidad and Tobago like most other small developing island states is vulnerable to changes in Climate and Sea Surface Temperature (SST). Climate changes can affect the rainfall regimes, air temperature, soil moisture budgets, water resources and arable land usage. Also changes in air and sea surface temperature can adversely affect coral reefs, mangroves, sea grass bed communities and fishery populations that depend on them for habitat and breeding grounds. Analysis of the temporal and spatial changes of SST over the years is an important way of understanding the present variability in the climate. This will then allow for an improved assessment of the susceptibility, vulnerability and risk that both humans and natural ecosystems may face because of the changes in the coupling interaction of the various components of the Earth's environmental system. However, decision-making, management and developing environmental policies in this regard is seriously compromised due *information poverty,* i.e. the lack of data of effective and reliable information base. This research, which formed part of an MPhil project, advances a methodology to obtain and analyse the SST patterns utilising it as a proxy for determining the climate variability of Trinidad and Tobago. The methodology is based on obtaining, using and analysing available remotely sensed SST from the National Oceanographic and Atmospheric Agency (NOAA) via the Internet. As well as using available rainfall data. In the case of Trinidad and Tobago, the SST and rainfall data was obtained for the last 16 years. Mean monthly values of SST and rainfall

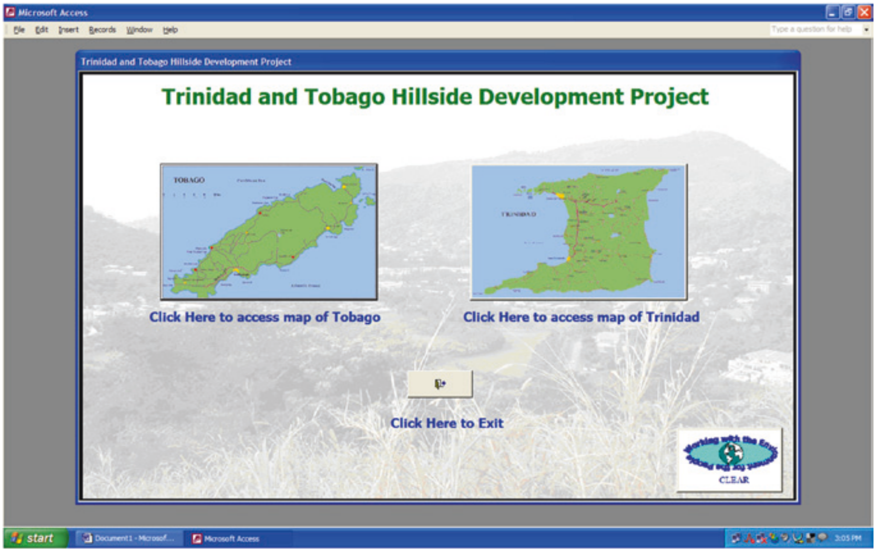

Fig. 6.13 Trinidad and Tobago Hillside development project (Baban et al. 2007)

for the period 1986–1999 were then derived. The results indicate that variability in the climate is occurring. Furthermore, it shows that during the El Niño years 1986–1987 and 1997–1998, the SST was at a maximum while the rainfall fell to minimum. Furthermore, the results indicate the possibility of developing statistical associations between SST and land precipitation as well as the association between the SST-land precipitation pattern and external events such as the El Niño Southern Oscillation (ENSO) phenomenon. These ideas in turn can lead to investigating the association between the variability in SST and land precipitation on water resources and land use patterns that might lead to the possible prediction of the land precipitation patterns based on SST analysis. This research was presented in a regional conference and published in the *proceedings of the Second Caribbean Environmental Forum and Exhibition (GEF-2)* (Ramdath et al. 2004) and later was published in the Caribbean Journal of Earth Sciences (Baban et al. 2005).

6.8.2 Sustainable Development

The Caribbean and in Particular Trinidad and Tobago tend to suffer from extensive inappropriate development on the hillsides which often lead to landslides which tend to endanger life and block important roads which disrupt commercial activities and isolate communities. My team was involved with planning for sustainable developments in hillsides (Fig. 6.13), this research was published as chapter in a book (Thomas and Baban 2008). The team also developed standards for safely manage hillside developments using Geoinformatics, this research was published in *the Journal of Sustainable Development* (Baban et al. 2007).

Another issues threatening sustainable development was the extensive and random distribution of gas stations in Trinidad, some of which in residential areas and lacked basic safety standards. My team using GIS developed an approach to rationalise the service stations. This research was sponsored and supported by the Ministry of Energy and Energy Industries, Trinidad and Tobago, the team submitted an extensive report to the Ministry which included standards as well as options and solutions for managing this issue (Baban et al. 2006c).

6.9 Sustainable Development Science and Management in Australia

6.9.1 Environmental Management

In Australia, the issues of climate change and its impacts on the coastal areas, wetlands and coastal coral reefs which are under threat are concerns. Hence, one if my Ph.D. students developed a Geoinformatics based methodology to examine the Potential Impacts of Sea Level Rise on Coastal Wetlands in North-Eastern NSW Australia (Fig. 6.14). The results showed significant changes in the coastal wetland communities from September 1989 to November 2003. This project was funded by Southern Cross University towards a Ph.D. studentship which has been successfully completed. Some of the outcomes from the research was published in the *Coast to Coast Conference* which was held in Australia (Akumu et al. 2008). Some other aspects of the research dealing with planning and management issues was published in the Journal of *Coastal Conservation: Planning and Management* (Akumu et al. 2011).

My team was also involved in a project which was focused on mapping and examining small marginal coral reef and examined the susceptibility of this reef to variations in their environment. The team developed a Geoinformatics based methodology to examine this supposition in terms of the change in coral reefs in response to changes in sea temperature and development on the shorelines in Burnett Mary in Queensland.

Geoinformatics was used for the collection and analysis of geo-spatial data including aerial photographs and Quickbird images collected in 2001 and 2008 respectively. Furthermore, fieldwork was conducted to calibrate and validate the data and to collect relevant water quality parameters. Other time series environmental parameters (i.e. sea surface temperature, chlorophyll a, and turbidity) derived from NOAA data were also analysed. The results showed associations between the coral reef and the variations in sea surface temperature as well as increased development activities nearby. Some aspects of this research were funded by Central Queensland University, Australia under a project entitled:

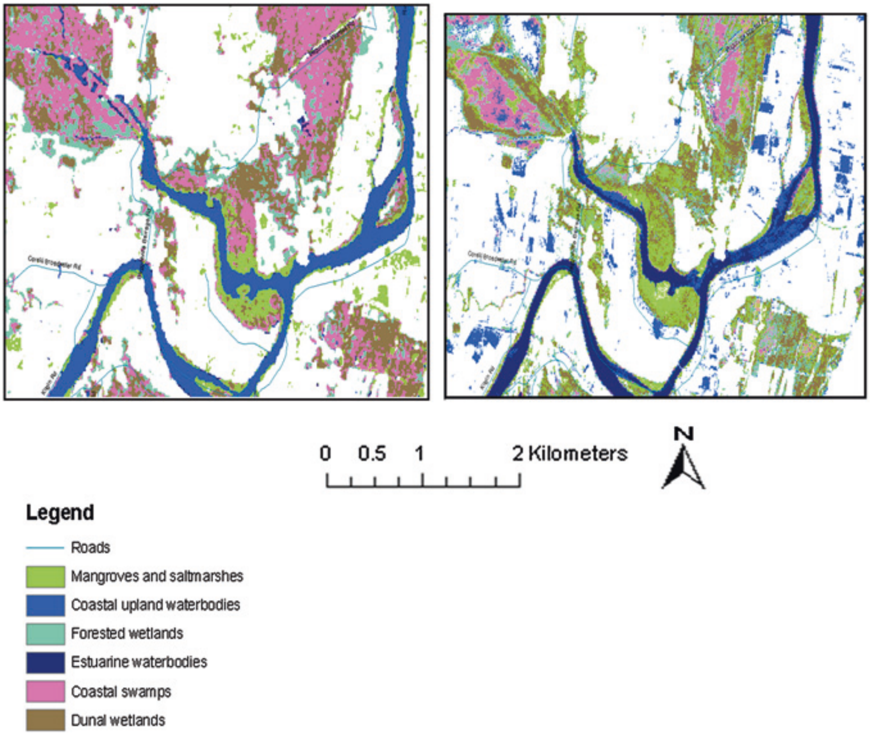

Fig. 6.14 Landsat TM 1989 wetland classes (*left*) and after 2003 (*right*) wetland classes in pink (Akumu et al. 2011)

'Mapping and examining Coastal Fringing Reefs in North East Australia Using Geoinformatics'. An extensive report was submitted to the sponsors (Baban et al. 2008).

Another issue needed research assessing Coastal Vulnerability to Climate Change and Anthropogenic Factors. My team focused this work in the coastal areas of Darwin, Northern Territory of Australia. The outcomes showed that the ongoing cliff erosion presents a challenge for the Council and a serious threat to infrastructure and the public in the urban areas near by which are in some cases only located a few meters away from the cliffs. Given the erosion processes described it is likely that the rate of shoreline recession will vary with the worst case being the collapse of large sections of the cliffs which could move back upwards of 5–6 m almost instantaneously therefore presenting a significant danger to infrastructure such as walls, housing and roads and also possibly to human life. The need for a sound management plan is overwhelming, based on the brief visit to the sites and available literature to the investigators. The team outlined various management scenarios that could be adopted by Council and possible coastal protection measures for the most vulnerable sections of Nightcliff and East Point. Furthermore, we recommended examining various sections in much more detail and to identify holistic and sustainable solutions for various sections of the coastline. The outcomes were presented in the 29th Asian conference on Remote Sensing, this was held in Sri Lanka (Pathirana and Baban 2008).

I also with colleagues investigated the impact of Climate and Land Cover/Use Variability on Vector Borne Diseases. More specifically the research attempted to understand the environmental indicators that influence two vector-borne diseases, namely dengue fever and malaria transmission using two study locations in Sri Lanka and the Solomon Islands. Time series analysis of climate data, epidemiological data and geographical data has been analyzed using GIS and quantitative techniques. The results show that some environmental indicators such as rainfall and hot humid climatic factors have a close relationship with dengue transmission, while malaria transmission is more closely related with hot, humid and wet forested areas and wetlands where population clusters are found. The less developed tropical countries are more vulnerable to these vector-borne diseases in comparison to similar environments in developed countries due to their adaptation and mitigation capabilities. Understanding of the respective environmental indicators and their linkages with particular infectious disease help planners and decision makers in controlling disease. This research was presented in the *28th Asian conference on Remote Sensing* which was Kuala Lumpur, Malaysia (Pathirana et al. 2007).

I was invited by Millennium House, Sydney, Australia to write a chapter reviewing climate change. This chapter was published within a reference publication entitled *Historical Atlas, A comprehensive history of the World* (Baban 2008b).

6.10 Sustainable Development Science and Management: A Conclusion

My research in this field started through involvement in supervising student projects, obtaining research projects and conducting consultancy activities. Furthermore, it has evolved as a response to my international activities, relocations and the need for managing sustainable development issues in the Jordan, Tunisia, Iraq, Malaysia and the Caribbean.

My aspiration is to assist in creating a sustainable future via developing reliable management options for decision-makers particularly in developing countries. I have always believed in translating my research into actions that can make contributions to the sustainable use of natural resources, mitigating the effects of climate change and improving the quality of life.

Water resources and in particular Lake management is a relatively new science whilst, the pollution and destruction of lake habitats is being carried out rapidly and on a global scale. Thus, minimising the damage, containing and/or attempting to reverse the degradation will require a clear understanding of relationships between loading of elements and compounds, and the structure and function of lake ecosystems. Though out my research, I have examined the issues related to lake management and provide and conceptual approach, using remote sensing and GIS, to effectively understand ongoing processes within lakes and developing lake management strategies. Remote sensing was used as an information source and GIS as an analytical tool. I have indicated that this combination will enable managers to; capture and update all the relevant information (e.g. water quality parameters), plan, simulate/implement, compare, visualise and evaluate the outcome resulting from simulating various management scenarios. Consequently, I believe that this approach, will help managers in making informative decisions and ultimately to adopt and implement the optimal course of action.

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Chapter 7
Higher Education and University Governance

7.1 Introduction

The last 30 years of lecturing, contributing to educational development Higher Education and University Governance has taught me that teaching and learning are constantly evolving and that an innovative approach is most effective. Throughout my career, I was instrumental in planning, developing, coordinating and implementing several degrees and courses at both undergraduate and postgraduate levels. I also developed a number of short courses as well as incorporating many new ideas on teaching and assessment methods. My involvement started at the University of Baghdad, Iraq, then Coventry University, UK, followed by the University of the West Indies, then Southern Cross University in Australia and the University of Kurdistan Hawler, Iraq. During my career, I have tried to make learning easy, simple, relevant, reflective and fun.

My teaching in general prescribes to the *deep learning approach* where students are encouraged to make sense of what is to be learned. This involves thinking and seeking integration between components and tasks. I have had success through practicing several aspects of teaching and learning in higher education. These include promoting active learning, building communication skills, debating objectively and presenting ideas clearly. Through my teaching, I have also adopted and encouraged student centred learning, hands-on practical sessions, and techniques helping in the development of transferable and group work skills. The supervision of undergraduate and postgraduate theses has become another important facet of my teaching development. All of these lead to a number of *educational developments* which include Computer Aided Learning; evaluating GIS for teaching purposes; designing and implementing specific projects to remedy problems associated with teaching environmental GIS technology at undergraduate level and developing strategies for teaching and learning Geoinformatics in higher education.

In terms of *teaching practice*, a strong two-way relationship exists between my teaching and research activities. The material in my courses is continually

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modified and updated to take account of recent trends identified from academic research as well as formal and informal student evaluation.

In order to satisfy my curiosity in terms of the learning processes. I attended a programme in Teaching and Learning in Higher Education and, having completed all the requirements was awarded *a Postgraduate Certificate in Teaching and Learning* in 1995 from Coventry University, UK.

In terms of managing and governing critical issues in Higher Education, I have developed my approaches and leadership skills and knowledge whilst being in post as the Chairman/Dean responsible for research and research training at the University of the West Indies, Head of School of Environmental Sciences and Management at Southern Cross University in Australia and the Vice Chancellor of Kurdistan Hawler, In Kurdistan Region, Iraq as well as having several other leadership affiliations and associations at national and international levels. I developed interests in mentoring staff, developing strategic, academic and financial plans, linking functions to form in terms of structures and work force functions. Besides developing workshops to energise staff research and provide guidance for obtaining research grants. In addition to sustainable learning and development, women leadership as well as innovative developments in Higher Education management and Governance.

7.2 Higher Education and University Governance in the UK

My first full time post in Higher Education was at Coventry University (Fig. 7.1), UK. This situation raised a number of issues and challenges. I had to find out what the department required of me in terms of teaching, research and administration. I was asked to teach Remote sensing and GIS, two new topics, so I had to work hard to design and prepare the necessary practical and tutorial sessions and also prepared the documentation taking into consideration classroom hours, size and number of groups taught and marking regimes. Then, I set out to acquire the necessary skills to teach which included;

1. Public Speaking, naturally, much of a lecturer's work involves public speaking in front of audiences of hundreds of people in large lecture theatres, an added difficulty in my case was teaching two new technology based topics in English to English native speakers.

   My personal experience through the university system as a student had subjected me to several lecturers who were extremely intelligent but simply could not convey ideas and information to students because of poor public speaking skills; hence, I was determined to acquire this skill. In the process, I learned the importance of controlling the nerves as well as the levels, pitch, tone and pace while speaking. My observations indicated that the majority of people

Fig. 7.1 My post, Research Unit and Tunisia Fieldwork with Coventry University Colleagues and Students, 1992–1998

speak too fast and too quietly with not enough eye contact with the audience, I concluded that nerves make most of us speak too quickly. This is backed by the fact that great orators such as Martin Luther King, tend to speak slowly and in reality it takes them a long time to say each sentence.

2. Time Management, having discussed my duties with some senior colleagues, it became apparent that time management is an essential skill to manage classroom time, preparation time, administration work and research. The advantage of the system was having the freedom to manage my time, however, the downside was having to be good at prioritising tasks and allocating them to spaces of time in my schedule. I was dealing with the requirements of several different mangers, including answering queries from numerous students, so I had to remain calm and focused under pressure. I had realised that planning and constantly assessing and reassessing progress are important, hence, I developed a system whereby I had an A4 page-per-day diary into which everything I had to do was written, to date, I still manage my responsibilities using this system.
3. Self-motivation, linked with point two is the skill of self-motivation. It is one of the joys of being in charge of your own working day that you can make it varied and tailor it to your own best working pattern, however, this relies on being able to motivate myself without the formality of having a line manager present. I learned that a secret to achieving self-motivation is a discipline, time management and to constantly define and assess the goals you are hoping to achieve.
4. Inter-personal communication, as a lecturer, it is important to be able to articulate your ideas on a one-to-one basis with students and your peers. This skill requires being able to maintain eye contact or reacting quickly to signals given off by your audience.

   I also found that the post required communicating with students on a personal basis as some students prefer to meet with the lecturers face to face to discuss problems with their work or their personal life. While not being a trained counselor, I understand the need to be able to put students at their ease and encourage them to discuss their issues, hence, mannerisms need to convey an 'open door' policy, heartening them to trust you as a mentor. This is very important if you are given the role of personal tutor.
5. Record keeping, I found that the post required good record keeping and being well-organised in both the physical office as well email/electronic filing systems. I had several hundred students in my care every year across several different courses so it was vital that to keep clear records as to their progress. These marks would be gathered gradually across the year. At the end of the academic year I had to submit these to a course leader or to a faculty administrator, so it is important to keep those records accurately and securely.

I noticed the need for developing student's communication skills and confidence; hence I developed some exercises to build these skills and to facilitate their active participation in tutorials and group work. This effort was published as part of a collection dealing with learning and innovation in Higher Education (Baban 1993).

Whilst at this post, I lead the development of one of the first B.Sc. degrees in Geographical Information Systems (GIS) in the UK Higher Education system during the early 1990s.

GIS is a multidimensional topic and it has developed from a number of data processing techniques including; Computer Cartography, Remote Sensing, Computer Aided Design and Data Base Management Systems. Thus GIS is based on a number of concepts and ideas across many disciplines including; Geography, Cartography, Spatial data analysis and Information technology. I discovered that these components and concepts, and the manner in which they interact with each other, were not familiar to the majority of students within the modular B.Sc. Honours degree run at Coventry University. Teaching GIS within a modular scheme is extremely difficult, as the level of student background knowledge in GIS is highly variable. An added difficulty is that a large number of variables need to be accounted for including; computing skills, apprehension, motivation and previous learning environment.

After some 5 years of teaching and during a reviewing process, I realised that the coverage of a wide range of concepts in the GIS course, in some cases, may appear to be fragmented in nature. This was then fully realised through student tutorial feedback sessions when some students found it difficult to view the GIS as a single entity with many components, and a clear distinctive philosophy. Therefore, I decided to develop and provide an integrated and holistic view of GIS combining all of the components and basic concepts. I also decided that this objective can best achieved by embedding it in an assessed project. The project format needed to facilitate and promote all the key elements of the 'deep learning approach' including; *motivational context, learner activity, interaction with others,* and a *well structured knowledge base* (Biggs 1989). In terms of selecting a 'topic', the basic idea was that the topic should act as a vehicle to carry the issues and concepts, which needed exploring. One of the most important characteristics of the topic is that it should be a familiar problem or idea; i.e. something that the students have an understanding of, so that they can use this knowledge to evaluate the outcome from the GIS process critically. The selected topic was the "Social and Environmental Quality of life in Coventry". It was chosen for two reasons; first, all of the students have been exposed to, participated in and developed an understanding of this problem by devising a sampling programme, collecting the data and creating maps to represent the spatial distribution of the measured qualities within Coventry. The issues for this particular topic were dealt with at level one within a Practical Geography Module. This means that the students would have an understanding of the process and have followed the stages; Real world, Observation, Sampling, Measurement and the Cartographic process. As this level one module is a prerequisite for the GIS module, it is safe to assume that all students would have had the experience. Secondly, by the time the project started, students would have lived for a minimum of 2 years in Coventry. They would have therefore formed ideas about the social and economic qualities within various parts of the city. This knowledge will be useful in critically evaluating the outcome from the GIS Project.

The project was implemented using a group work format. Project evaluation through student questionnaire feedback revealed that the design, implementation, learning format and environment were effective. It also showed that the central objective of establishing a holistic overview of GIS as one entity was fulfilled. Furthermore, the project was found to; enhance and add to student knowledge and understanding of GIS, provide a mechanism to reflect on the whole process (starting from sampling the real world and ending by implementing the findings to the real world) and build confidence regarding GIS usage. This research was published in the *Journal of Geography* (Baban 1998).

I also developed and taught a second year introductory course in Remote *Sensing and Image Processing Techniques* during 1994. A key feature of the course was an attempt to adopt a progressive and an integrated approach based on understanding and active learning. During the revision process, I thought that some of these objectives could be best achieved by adopting the deep learning approach. In this approach, the students are encouraged to make sense of the ideas and concepts to be learnt. This involves thinking and seeking integration between components and between tasks. Key elements of the approach are motivational context, learner activity, interaction with others and a well-structured knowledge base (Entwistle and Ramsden 1983; Biggs 1989). The latter is mainly focused on building new concepts based on old ones and relating knowledge to other knowledge rather than learned in isolation.

An attempt was made to enhance student learning and understanding of remote sensing by running a series of tutorials designed to accommodate all the requirements for the 'deep learning approach'. The tutorials were implemented using a group work format and the Star Trek series. Relevant concepts and issues were explained and discussed in each tutorial before hand. The students were then asked to complete a specific task individually and to scientifically justify their approach within a small group based on the theoretical and practical knowledge gained in the Remote Sensing module and what is possible using Star Trek technology. The tasks included requests to design or reconfigure existing sensors to detect particular features based on provided spectral information or attempting to determine the existence of civilisation on a nearby planet based on sensor readings. Tutorial evaluation through a student questionnaire indicated that the implementation approach and the learning format were effective. Furthermore, the objectives in terms of motivational context, learner activity, interaction with others and a structured knowledge base were fulfilled. Moreover, the tutorials seem to enhance and add to student knowledge and understanding of Remote sensing, provide a mechanism to locate the scientific knowledge gained during the module in a wider context and to build confidence regarding potential Remote sensing usage. This work was developed under the heading *Using Star Trek and The Deep Learning Approach To Take Remote Sensing Where It Has Not Gone Before* and it was published as a paper in the *proceedings of the Remote Sensing 2000 conference* (Baban 2000). In addition I promoted the use of Remote sensing and GIS as two complementary tools whilst focusing on the activities of the my research group (GRRU) both nationally and internationally (Baban 1995). Within this effort, I managed, in collaboration with and Dr. A. Barazanji from University of Wales, Cardiff, UK, to obtain funds from the British Council in Jordan to develop and implement a Short Course in GIS and Remote Sensing for Jordanian Scientists working in the areas of geology and water resources management at Jordanian Universities.

By this stage, I was becoming interested in the history of teaching Geography using computers, which have inevitably been linked to developments in information technology (Maguire 1989), and the demand for graduates with such skills (Green and McEwen 1990). These facts have been widely recognised and, as a result, many academic geography departments in the UK have invested in computing facilitates during the 1980s (Taylor and Johnston 1995). I noted that this action had two major impacts on undergraduate geographical teaching. First, the creation of courses that make a technology, such as Remote sensing and GIS, an object of study in which the focus is acquiring new knowledge *about* Remote sensing and GIS technologies. Secondly, the technology has also been used as a tool for teaching and studying geography, in which the focus is conveying knowledge *with* remote sensing and GIS technologies. Whilst the majority of the Universities have taken this path, some were more successful than others. Hence, I was interested in assessing the departmental usage of Remote Sensing, GIS and the World Wide Web (WWW) in geographical education at Higher Education in the UK. In addition to attempting to appraise the potential trend for future usage and to understand why certain institutes seem to be more successful than others.

This interest led to several educational developments funded by the 'Higher Education Funding Council, UK' as an active member of the 'UK computer assisted learning consortium in Geography' to develop several teaching and learning programmes to promote the use of computers in teaching Geography within the UK Universities and Higher education institutions. Relevant to this activity, Maguire (1992) has identified the key elements in teaching geography using computers in general as; hardware, software, data and liveware. The perceived importance of each element has changed over time. The hardware element has been declining since the 1970s, the software element peaked in 1987. Data have been steadily increasing in perceived importance while liveware appears to have peaked during the early 1990s and has slightly declined since.

Potentially, new technologies can make a significant improvement to the quality of teaching and learning in geography and ultimately to geographical understanding. There is little tangible evidence that they are being used to their full potential (Shepherd 1985; Reeve 1985). My own experience was indicating to me that GIS is a valuable resource alongside remotely sensed information, fieldwork, and textbooks. It can be easily used for improving student learning of concepts, principles and facts. It can also help to bring the real world to life, giving graphical representation (Thompson 1987). The WWW also has a vast potential for education at all levels, it can provide educators and students with fresh and virtually instantaneously information. It also allows the transmission of video, sound, text, animation and graphics (Ingram 1994; BBC 1995; Kitchin 1995).

My feedback sessions with the students indicated that the students expected to be offered the opportunity to acquire not only substantive knowledge in geography but also a range of transferable skills that can be applied when they enter the workplace. Future geographers are expected to have the necessary skills to manipulate and analyse available data sets (Green and McEwen 1990), via the WWW, often using Remote Sensing and GIS. Therefore, an understanding of how to handle and analyse digital spatial data is considered to be an important part of a geographer's education and training.

My study aimed to examine the usage of Geographical Information Systems (GIS), Remote Sensing (RS), and the World Wide Web (WWW) for teaching and learning within Geography in higher education, in addition to examining the potential future usage of all three technologies. A questionnaire was used to gather the information targeting all geography departments in the UK of whom 41 were returned giving a response rate of 51.2 %. All institutions were ranked based on their usage of each technology, and an overall usage ranking was calculated. Institutions achieving a higher than the average usage scores were identified for Remote sensing, GIS and WWW respectively. It was obvious that a large proportion of institutions surveyed were not fully aware of the variety, depth and potential usage of information accessible via the WWW. From the analysis, it was apparent that there is a correlation between the individual usage of these technologies within each institution and an overall expectation for increasing usage of all technologies in the future. Overall, traditional Universities had the highest ranking for each technology as well as the overall usage of all three technologies. This research was published in the *Journal of Surveying and Land Information Science* (Baban 2002a).

I noticed that the increase in student numbers has been associated with a substantial decrease in staff/student contact. This could have a direct effect on the learning process and could lead to lower standards. One way to minimise this possibility was by encouraging active learning through working in groups hence assisting students with sharing information and also increasing their communication skills and making them more visible in class. I developed an exercise to deliver these objectives and this work was published in a refereed chapter in a book (Baban 1993).

7.3 Higher Education and University Governance in the Caribbean

During September 2000, I was offered and accepted a post as a Professor of Surveying and Land Information in the University of the West Indies (Fig. 7.2). The Caribbean region, which consists of many small islands that span a large geographical area, faces numerous challenges in ensuring that it has sufficient numbers of qualified personnel to meet its developmental needs. As the only professor in my discipline at the University of the West Indies I was interested and obligated to find out if Geoinformatics Education provided by the University was

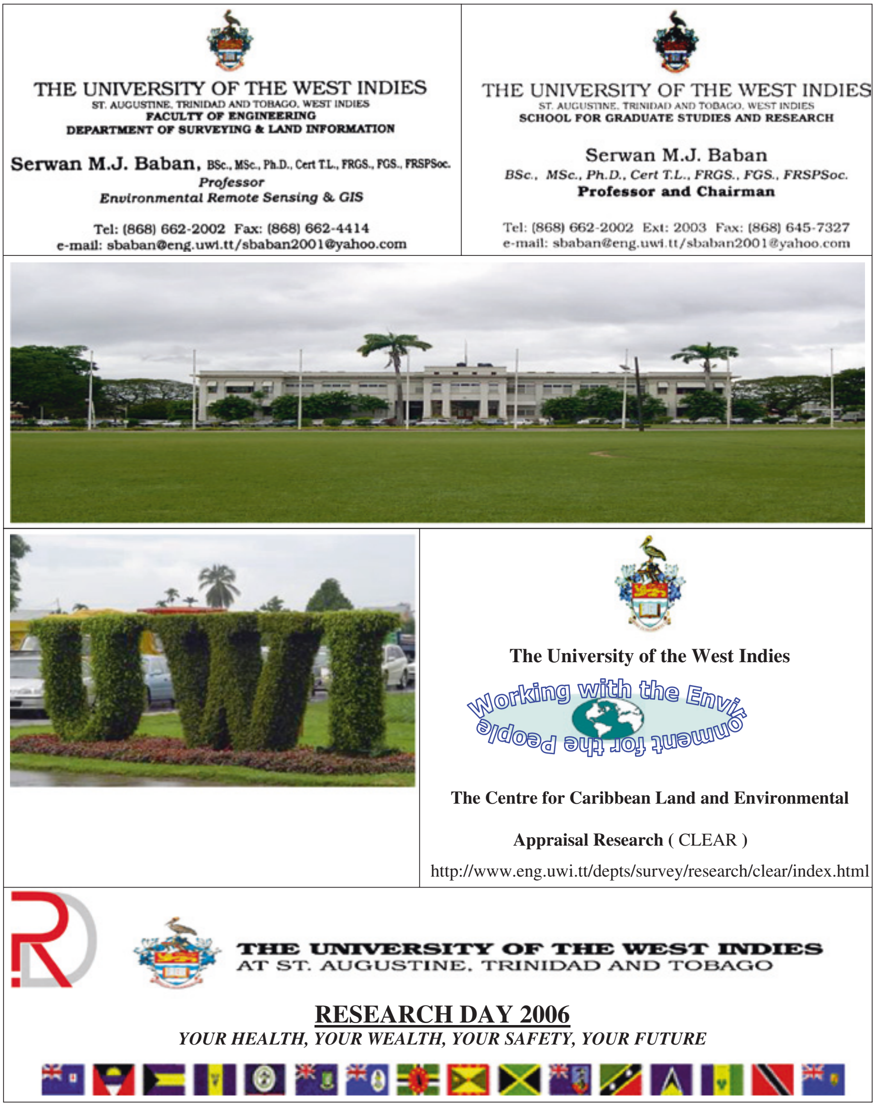

Fig. 7.2 My posts, Research Centre and Research Day 2006 at the University of West Indies

meeting the needs of students in the Caribbean Region. Hence, I reviewed a range of services and activities offered including; Geoinformatics education, research, development as well as extension activities. This research was published in the *International J. of Geoinformatics* (Baban et al. 2005). I also examined the indicators for determining the success of GIS technology within local government departments in both developed and developing countries. This was an analysis for the uses and implementation strategies for GIS in both the UK and the Caribbean region; it was published in the journal *of Surveying and Land Information Science* (Baban and Ramlal 2006). I also developed and presented a paper in Regional Workshop on using Geoinformatics to manage Land Degradation in the Caribbean, during 2004 held in Trinidad (Ramlal et al. 2004a).

In terms of c*urriculum development*, at the University of the West Indies, I developed and coordinated an M.Sc. degree in Geoinformatics which was designed to address the specific needs of the region for Geoinformatics specialists. This program allows flexibility in areas of concentration, research and professional options, and a completion time of 18 months. The philosophy and major objectives of this program were examined. The program's entry requirements and structure were then presented. Plans for further development were discussed and conclusions presented. This research was published in the Asian Journal of Geoinformatics (Ramlal et al. 2004b).

I also contributed to a 'travelling' certificate in GIS. Besides developing and managing new M.Phil. and Ph.D. programs with particular emphasis on understanding and attempting to manage environmental and development challenges in the Caribbean region, I was also involved in developing an M.Sc. programme in Forestry and an M.Sc. Programme in Coastal/Marine Science and Technology. I also developed several undergraduate courses and postgraduate courses as well as a number of short courses including courses in Environmental GIS and Remote Sensing, Geoinformatics for Environmental Engineers and Geoinformatics for Forestry.

I developed several handbooks and information documents to providing basic Information on Postgraduate Research Opportunities and Staff Research Expertise and Activities (Baban 2001a), M.Sc. Geoinformatics Student Handbook 2002–2004 (Baban 2002b) and M.Sc. Geoinformatics Student Handbook 2005 (Baban 2005a).

During this period, I became involved with promoting environmental education and participatory decision making in the Caribbean Region using Geoinformatics through working with a number of NGO's such as the Cropper Foundation and Buccoo Reef Trust as well as Community Leaders in Trinidad and Tobago.

I continued promoting the use of Remote sensing and GIS into various applications and developed a Research Agenda to Minimise Environmental Degradation in the Badia Region, Using these technologies and presented it in an international workshop dealing with water management during 1999 in AL al-Bayt University, Mafraq, Jordan (Baban 2001b) and published it in an extended form as a chapter in a book (Baban 2002a).

When I became the Dean/Chairman, School of Graduate Studies and Research at the University of the West Indies, I noted that some colleagues and research students were very reluctant to write and publish in Peer-Reviewed Journals. I was taught early in my career that writing is the best way to communicate new ideas and concepts to interested parties and that the objectives of a research project are only completely met when the findings are published as a scientific paper. Furthermore, publication of articles in peer-reviewed papers can benefit the authors in many ways. Such publications are likely to satisfy the criterion for promotion and career advancement world wide, increase the circle of professional acquaintances, and encourage ideas and responses from interested parties. Therefore, it was something of a paradox that many researchers, both experienced and inexperienced were reluctant to write. This is understandable of the new or novice researcher, who may have little idea of what might be expected particularly when effective mentoring is not provided. Among more experienced researchers, a dislike for the writing experience in journals, I thought, may partly be due to a continuing lack of confidence in their abilities.

Recently, there has been a significant increase in the number of papers submitted for publication to quality journals worldwide. Some could argue that this is caused by institutional requirements for research ranking or the requirements for personal promotion in Higher Education Institutions worldwide. As a result, it became even more difficult for inexperienced researchers to publish in quality journals. Hence, a large number of papers are either rejected or returned with a request for major revisions. I learned from my refereeing activities that this is on many occasions due to reasons other than the quality of the work. Therefore, I, in collaboration with Professor Sankat, set out to assist young or more established but reluctant researchers with writing papers that can convey the information in an easy to understand way and stimulate the interest of the reviewers and the editor. I attempted to provide guidance on the process of writing and publishing in a peer-reviewed journal. In addition to the requirements for organization, structure, argument development, the composition of various sections in a paper as well as how to target the most appropriate journal and readership. This research was published in the *West Indian Journal of Engineering* (Baban and Sankat 2003).

I moreover became concerned with the lack of successful completions of M.Phil./Ph.D. thesis within regulation time. Once, I examined available practices and procedures, I formed a view that this task requires the existence of a structured and transparent framework to set out the stream of events, benchmarks, achievements and deliverables against a time scale. This will allow both the supervisor and the student to develop reliable working habits and to have some measure as to how the research is progressing. As the research student is expected to work relatively independently on an original research project. This process requires developing a range of skills as well as trekking through the full range of research planning, actioning, extracting conclusions and communicating the methodology and the outcomes (Whisker 2005). They are also meant to work with a research supervisor who will share their research interests and area of expertise (Blaxter et al. 2001). A successful completion of M.Phil./Ph.D. thesis within regulation time requires a supervisory relationship that respects autonomy, facilitates scholarly independence and fosters academic values such as exchange of information, social responsibility, critical thinking, self reflectance and personal growth (Phillips and Pugh 1996; Mackinnon 2004). In addition, the student and the supervisor need to thoroughly fulfill their responsibilities and to work mindfully according to a planned timeframe.

I noted that in the case of M.Phil. and Ph.D. students, in the majority of the cases, delays and lack of completions is a long standing problem where students tend to seek extensions, leaves and take much longer time to complete. This phenomenon can be due to the lack of a planned and disciplined approach to research or good supervision coupled with the temptations to undertake other activities or employment during the on going M.Phil./Ph.D. degree. In other cases the students tend to have difficulty in managing their time or simply lack some essential technical, statistical, analytical or Information technology skills (Phillips and Pugh 1996). In some other cases the students lack the ability to write and to complete tasks on time, this combination of deficiency is damaging as a substantial portion of the successful completion of a M.Phil./Ph.D. degree lies in having the ability to write an in-depth and coherent thesis. Besides, almost all scientific activities carried out by the majority of professional people in their subsequent careers have to comply with and adhere to predefined time scales. Consequently not having these skills will significantly delay completion and could hamper success in professional life. It is evident to me that the existence of a framework, accepted within the department/faculty, defining the stages which a student should be expected to have completed at various points in the 3 years period of study, would help to reduce these delays (SERC 1992; Booth et al. 1995). Students need to be introduced to planning and time management at a very early stage. Students will be helped by knowing that they are expected to reach certain stages at certain times and will come to accept that part of their training is, in fact, learning how to manage their time and organise their affairs.

This study aimed to assist with securing satisfactory M.Phil./Ph.D. research progress by outlining the main reasons for non-completion of thesis on time. It also offers advice and proposes a framework containing specific benchmarks, from beginning till the completion of research, which can ensure good, steady and satisfactory progress. It is hoped that this approach will assist the supervisor and student to detect progress and perhaps more importantly when to introduce intervention mechanisms when the research is not progressing according to plan. This work was published as chapter in a book dealing with conducting research (Baban 2009b).

I wanted in a broad sense to stimulate thinking and indicate topics for discussion and clarification between the students and their supervisor's. More specifically I aimed to assist M.Phil./Ph.D. students with writing their thesis by providing guidance on the processes involved, advice on the writing up, structure and organisation. In the case of M.Phil./Ph.D. degree, it is assumed that the research is captured in the thesis, therefore the thesis is the pinnacle of a student's research programme, and it is on the thesis that he or she will be assessed, probably in association with an oral examination or viva (Phillips and Pugh 1996). In fact all M.Phil/Ph.D. students need to communicate their findings; the M.Phil/Ph.D. thesis is a seen by many as the formal document that provides training for communication with other scientists. Some will even argue that writing leads to identifying gaps and aids the discovery process as it makes people think about their work in a logical and critical mode (Phillips and Pugh 1996). Thus, writing a thesis requires a student to think analytically about the structure, content, organization, grammar, style as well as developing strong technical arguments to persuade other scientists, and to present these within the convention for formal presentations. Each statement in a thesis must be correct and justifiable in a logical and scientific sense. If the student has difficulties with the writing processes and in communicating ideas then, it is important to minimise misunderstandings and to find out as early as possible where he/she is not functioning properly. Strategies to manage these shortcomings include; giving departmental seminars and conference presentations as well as writing journal articles. Additionally, students should try to find someone new to their work that will listen to their explanations or is willing to read the draft thesis and tell them if they have difficulties following it. There is no uniform view across disciplines about what constitutes a satisfactory thesis, either for a degree entirely by research or for an award with a research component. Consequently, the thesis is expected to define the problem that motivated the research, explain why that problem is important, inform on the literature of the topic, describe the new contribution, document the experiments that validate the contribution, and draw conclusions. This work provided guidance on the process of writing an M.Phil./Ph.D. thesis. The requirements for organization, structure, argument development and the required composition of various chapters have been discussed with the view to help students to develop and write a successful thesis. This work was published as chapter in a book dealing with conducting research (Baban 2009c, d). I also researched background information and hands on exercises to define issues such as what is research?, characteristics of research, originality and thinking in research, the research processes, making good research arguments, sampling, data collection and analysis (Baban 2009d, e, f, g, h). Furthermore, I developed work to enable graduate students to successfully write a research report, write to publish in peer-reviewed journals and provided and introduction to the reviewing/refereeing process (Baban 2009c, d, e, i, j, k, l).

I also developed Papers to Energies Graduate Education and Research. These included Providing the Building Blocks for Research Excellence in the University of the West Indies (Baban 2003a), Developing an Environmental Research Network (Baban 2003b), A proposal for developing a Split Site Ph.D. Model at the University of the West Indies (Baban 2003b), a Proposal for Restructuring the Management of Taught and Research Based Degrees in the School for Graduate Studies and Research (Baban 2004), Developing an Effective Format for M.Phil. and Ph.D. Progress Reports (Baban 2005a), Developing Induction Packages for M.Sc. and M.Phil./Ph.D. students (Baban 2005b), developing an effective format for M.Phil./Ph.D. progress reports (Baban 2005c), Conducting Research, the First Steps (Baban 2006a), Accomplishing Research (Baban 2006b) and Writing up Research Baban 2006c). These efforts lead to the practical steps of developing and running interactive workshops for Research students and staff to strengthen research and research outputs through developing the Building Blocks for Research Excellence, These research activities were sponsored by the University of West Indies.

I have published a book dealing with research approaches and methodologies as well as implementing and writing research proposals to obtain funding and to publish findings in refereed journals (Baban 2009a). This project was supported by the Royal Bank of Trinidad and Tobago Education Fund as well as the University of the West Indies.

7.4 Higher Education and University Governance in Australia

I joined Southern Cross University (SCU) in Australia during 2007, as the *Professor of Environmental Geoinformatics and Head, School of Environmental Science and Management* (Fig. 7.3). After a period of observation and acclimatization the country and the work culture and ethics in the University. The need for leadership and for change was evident, the senior management agreed with my conclusions and supported my fledgling plans. I, through a collaborative process, developed and implemented a transparent, inclusive management model to handle the core areas of teaching, research and University service within the School. I also established a strategy group for the School to develop ideas for sustainability including a clear brand/identity, developing focused team based research areas, a practical mentoring system, rationalising course offerings and teaching load. I moreover implemented several policy papers to manage both routine and strategic issues within the School. I am happy to report that the School became financially secure; in fact it had a surplus for the following year, an event that had not occurred for several years and the student intake rose, against the national trend in Australia.

In order to continue with my research and develop new relevant areas to Australia, during 2007, I established the *Centre for Geoinformatics Research and Environmental Assessment Technology* (GREAT) (Fig. 7.3). This centre was aiming to:

- Develop and lead a multidisciplinary team, establish national/international collaboration and obtain funding for research.
- Identify the impact of a range of development and human activities on the environment and to propose a range of operational measures and solutions which may be used to achieve sustainable natural resource management.
- Lead and promote sustainable development and sensible environmental and natural resource management by means of evaluating the current state of the environment-related fields underpinned by Geo-sciences through collecting, analysing, managing and disseminating geo-based information on natural resources and the condition of the environment.

I was satisfied with my performance in this role as my team was established in short period of time and began to gain recognition in Australia and beyond as evidenced by the increase in postgraduate applications to work in Geoinformatics as well as obtaining several research, consultancy and professional training grants. These included developing an intensive course in GIS for Scientists and Engineers from Saudi Arabia, a project on managing coastal erosion issues in Darwin, North Australia; managing climate change issues in the wetlands of New South Wales; developing coral reef habitat based indicators for climate change in Australia and developing a Geoinformatics based early warning system for floods in Trinidad.

Fig. 7.3 My post, research centre, fieldwork with students and a visit by Prof. Chris Vincent, Dean of the School of Env, Sciences, University of East Anglia, UK

Achievements during this period also included; invited membership of the Scientific Committee, *Current Trends in Remote Sensing and GIS Application*s a Conference held at the Indian Institute of Technology, Kharagpur, February 15–17, 2007, West Bengal, India; invited participation and presentation in the

United Nations Regional UN-SPIDER Workshop: Building Upon Regional Space-based Solutions for Disaster Management and Emergency Response for the Pacific Region. This was held Suva, Fiji, 16–19 September 2008; invited membership of the Scientific Committee, *the 2nd International Conference of GIS/RS in Hydrology, Water Resources and Environment (ICGRHWE'06) and the 2nd International Symposium on Flood Forecasting and Management with GIS and Remote Sensing (FM2S'06)*, co-organized by Sun Yat-Sen University of China, Bristol University of UK and Kyoto University of Japan, this conference took place during September 17–23, 2007 at Guangzhou, China; invited membership of the International Scientific Committee, *the International Groundwater Conference, Groundwater India 88*, co-organized by University of Rajasthan, India, Planet Earth and UNESCO. It was held during March 19–22, 2008 at the University of Rajasthan, Jaipur, India. Furthermore, I was an invited member of the international advisory committee for *the Second International Conference on Geoinformatics Technology for Natural Disaster Management and Rehabilitation.* It was held during January 2009 at the Asian Institute of Technology (AIT), Bangkok, Thailand. I was also an invited member of the international advisory committee and invited Keynote Speaker for *ISA-RC-24- International Conference on Water, Environment, Energy and Society.* This conference was held during June 28–30, 2009 in Firozabad Agra, India.

7.5 Higher Education and University Governance in Kurdistan Region, Iraq

Whilst abroad, I maintained my links with the Universities in Kurdistan through research collaboration and frequent visits to familiarize colleagues in the University of Salahaldeen, Erbil, the University of Sulaimani, Sulamaniya with research methodologies, new innovations and technologies through lecture series and workshops. These activities were partially funded by Ministry *of Higher Education in the Kurdish Regional Government, Iraq* during 2009.

In Australia, I became homesick for Kurdistan, I kept thinking about my extended family, friends and the delicious Kurdish food. Once, I turned 50 years old, I almost became infatuated with going 'home'. The possibility of having Australia as my permanent home and when dying, the mixing of my body with anything other than Kurdish soil was at that time very disturbing to me. I started to seek opportunities at Kurdistan, one day, whilst examining the Times Higher Education Jobs on line, I noticed, an advertisement for a global search for a Vice-Chancellor for the University of Kurdistan Hawler in Erbil. I sent in my completed application form and waited patiently and hopefully. I was shortlisted and invited for an interview. The international appointing committee and interview panel consisted of senior academics from Lancaster University, UK; University of Pennsylvania, USA, the Kurdish Institute of Paris and local universities as well as a member of the Governing Board and the committee was chaired by the Chairman of the UKH Governing Board. During August 2009, I was appointed as a *Professor of Geoinformatics and the Vice Chancellor* (Fig. 7.4) for the University of Kurdistan-Hawler (UKH), Federal Region of Kurdistan, Iraq.

I soon realized the need for continues learning and professional development for University staff in a partnership with international universities. I have managed in collaboration with Professor Gina Wisker of the University of Brighton, UK to obtain funds from the British Council under the DelPHE-Iraq, preliminary round One programme during 2010 under a project entitled' Connections for sustainable change: University of Brighton and UKH partnership in learning and professional development'.

My collaboration with Professor Gina Wisker of the University of Brighton, UK also lead to obtaining funds from the British Council under the International Partnership Scheme 2010–2011 to develop mechanisms and sustainable arrangements for female academics in Kurdistan region through workshops as well as establish a female academic network in the region. The funded project was entitled 'Women's Leadership Development'

In order to continue with my research and develop new relevant areas to Kurdistan and the wider region, during 2009, I founded and directed *the Geoinformatics Institute for Future Threats to Sustainability* (GIFTS) (Fig. 7.4). GIFTS was founded at the University of Kurdistan Hewler to provide advice on, investigating, mapping, monitoring and managing processes and issues impacting Sustainable Development in Kurdistan and the wider region. GIFTS is committed to informed decision making, contributing to the next phase of economic and social development and in influencing future development choices for the future of Kurdistan and the wider region. More specifically it aims to;

- Advance multidisciplinary research and development in Geoinformatics and geo-based sciences in general and in new relevant technologies such as remote sensing and GIS in particular.
- Provide the infrastructure to foster interdisciplinary research in Geoinformatics, Sustainable Development and Environmental Geo-based solutions.
- Assist with expanding and strengthening Geoinformatics, Environmental and Geo-spatial research, consultancy and outreach at all levels.
- Foster capacity building and encourage the dissemination of research findings
- Actively involve the organization of local, national and international conferences
- Strengthen environmental and geo-spatial education
- Ensure scientific and technological solutions are brought to bear on problems

In addition, I introduced External Examiners to ensure the quality and standards of the examinations, developed a process for validating new programs to ensure that the academic portfolio meet the highest international standards and at the same time address the needs of Kurdistan, focused on matching graduates to market needs, as Graduate employability is a priority, hence this year we

Fig. 7.4 My post and some activities at UKH 2009–2012

also organized Self awareness, CV Preparation and Interview Skills workshops followed by a career fair for our graduates. Furthermore, I managed to develop and implement two new Masters Programmes in Business Management and International Studies, Staff members obtained higher Academic qualifications;

Two completed their Ph.D.'s from international universities, 5 obtained their PGCET in Teaching and learning from the University of Brighton, UK, Two staff members attended Training in the UK on Supervising Ph.D. students and projects.

I have developed an interest in examining the role of government Higher Education Institutions in the Process of Nation building, published this research was presented in the First World Kurdish Congress (WKC2011), October 2011, Rotterdam, Netherlands (182) and was later in a more comprehensive form as chapter in a book (Heshmati et al. 2013). As the reform in Higher Education in the region was initiated, the issues of University independence and reforming the curriculum to build a relevant 'graduate profile' were being examined heavily, I contributed by proposing the Governance, management and academic organization and quality assurance mechanisms of the University of Kurdistan Hewler, a Possible Model for Establishing Independent International Universities within the Region and Developing Countries. This work was presented in the Second Scientific World Kurdish Congress (WKC2012), October 2012, in Erbil, Iraq (Baban 2011), later it was revised and published as chapter in a book (Baban 2013).

I was offered further opportunities for Higher Education leadership and University Governance at the national and international levels. These included leading the Kurdistan team which participated in the in the Knowledge Economy Study Tour to South Korea and Malaysia orgaised by the World Bank as well as working on the National Education Strategy for Iraq (Baban and Amin 2011). Furthermore, I participated in the visit and the discussions with Bank specialist in Washington D.C, USA which focused on the Education and Higher Education Strategy for Iraq (Baban 2011).

The University has managed to developed significant international collaborations with British Universities including the University of Leicester (Fig. 7.5) and University of London (Fig. 7.6) and Brighton Universities.

In addition managed to consolidate a successful Student Exchange Programme in Politics and International Relations with the University of Amsterdam.

Two significant events took place during my Vice Chancellorship at UKH, the First was the inauguration of H.E. Nachirvan Barzani as the first Chancellor for the University of Kurdistan-Hawler (UKH) during March 15, 2010. A ceremony was held at the University, The Vice Chancellor and Dr. Shafiq Qazzaz, the Chairman of the Governing Board of the University of Kurdistan-Hawler gave speeches and introduced his Excellency to the university community (Fig. 7.7). Then a presentation of documents verifying the appointment and a university Chancellor gown followed. The Chancellor told the audience, "It is a great honor for me to be appointed Chancellor. I hope I am worthy of your trust in honoring me with this post". Furthermore, Chancellor Barzani addressed the audience and said, "Universities are centers for learning, production, and research, helping us progress towards a better future for our people. Before 2003 and the liberation of Iraq, Kurdistan was cut off from the outside world. With all of the difficulties in front of us, there was nothing to support the progression of education in Kurdistan".

Fig. 7.5 University of Leicester celebrations

The second event was the University granting an Honorary Doctorate in Politics and International Relations to Sir John Major (British Prime Minister 1991–1997) during his visit to Kurdistan in May 2011. UKH Governing Board decided to grant this Honorary Doctorate based on the outstanding achievements

Fig. 7.6 University of London celebrations

Fig. 7.7 H. E. Nechervan Barzani receiving his Chancellorship of UKH on March 15th, 2010

of Sir John Major in the field of International Relations and Politics, and the significant role he played in shaping international policy towards recognizing Kurds rights and establishing the federal government of Kurdistan. The degree was presented to Sir John Major's by Professor Baban, Vice Chancellor of UKH during Prime Minister Visit to UKH campus (Fig. 7.8). This event was attended by Vice Chancellor of UKH Professor Serwan Baban, the British Ambassador to Iraq, British Consul to Kurdistan, Mrs. Bayan Sami Abdulrahman KRG's Higher Representative to the United Kingdom, members of the Governing Board, senior KRG ministers, and a number of university presidents and government officials and over 300 students and faculty members from UKH and Salahudin university.

Overall, I am proud of my performance in this role as the University of Kurdistan-Hawler was consistently ranked within the top 5 Universities in Iraq during my Vice Chancellorship. Furthermore, the University was established as it has managed to successfully graduate two cohorts, developed significant international collaborations with British Universities (Fig. 7.9).

7.6 Higher Education and University Governance: A Conclusion

The longing for more information regarding the environment and natural resources has been increasing steadily among Geo-based Environmental Scientists over a number of years. Paradoxically, greater knowledge of the earth and the environment has led to a wider recognition of the existing gaps in this information. One of the ways to bridge this information gap was through the use of Remote Sensing (RS) (Curran 1985). Naturally, as the demands for Remote sensing education grew universities responded by developing relevant courses. However, this process posed a new problem as spectral Remote Sensing produces excessively large volumes of raw spatial data requiring further processing and analysis. Computer specifications at that time, set severe limits to the size of data sets which could be analysed and the type of spatial analysis being performed. Geographical Information Systems (GIS) was developed while attempting to break those boundaries with increased data storage, manipulation and analysis capacity using later generation computers (Maguire 1992; Taylor and Johnston 1995). Since then, GIS has undergone a rapid rate of theoretical, technological and organisational development, evolving as a means of collecting and analysing spatial data. Consequently, GIS experienced a sharp increase in demand; i.e., new journals, sales of software, and consultant reports. The academic system responded again by developing courses and degrees in GIS and more recently combined both Remote sensing and GIS under the term Geoinformatics.

My contribution to. Higher Education and University Governance in general and Geoinformatics Education in particular has been through developing Geosciences, Remote sensing, GIS and Geoinformatics courses and degrees at both

Fig. 7.8 Sir John Major visit to UKH during May 2011

Fig. 7.9 Meeting Key Players; *top* two successive Ministers of Higher Education in the Kurdistan Region; *Next row* World Bank senior officers; *Following row* British Minister of Science and the Ambassador; *bottom* HRH Prince Hassan of Jordan and the Turkish Minister of Education

undergraduate and postgraduate levels. This work began at Coventry University in the early 1990s and continued at the University of the West Indies, Southern Cross University in Australia and Kurdistan University Hawler, Iraq. I became very involved with graduate education in the West Indies through managing the School of Graduate Studies and Research on Campus, then I learned that we are true captives of our first degrees in how we view the world, develop solutions and most importantly communicate and teach.

Through my journey of three decades, I also contributed and shared my experience with colleagues from Jordan, Tunisia, Malta, Iraq and Malaysia. I have also attempted to make teaching and learning less taxing and relevant to student's life experiences, attempting to respond to student needs through modifying and reviewing my teaching material and continuously upgrading my teaching/delivery methods. Having worked in different parts of the world while embracing different cultures, I have learned that listening to and keeping student's learning central to University teaching and research are essential skills for lecturers.

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About the Author

Born in Kirkuk in 1958, Professor Baban gained his *B.Sc. in Geology during* 1980 and *M.Sc. in Geophysics in* 1983 both from the University of Baghdad. Then he was appointed as a *Geophysicist* and *Deputy Exploration Party Manager* working for the Iraqi National Oil Company until November 1986. Professor Baban obtained his *Ph.D. in Applied Remote Sensing* and his *D.Sc. in Geo-based Environmental Challenges* from the prestigious School of Environmental Sciences, the University of East Anglia, UK in 1991 and 2011 respectively.

Professor Baban's *academic, research and consultancy career* was developed through working in universities in the UK, The Caribbean, Australia and Iraq. During 1991–1992, he worked as a *Research Assistant* and *Senior Research Associate* in the School of Environmental Sciences, the University of East Anglia, UK. Then from 1992 and until 2000, as a *Lecturer* and later a *Senior Lecturer* in *Geosciences/Physical Geography* at *Coventry University, UK*. Then, he moved to the University of the West Indies during September 2000 to become the *Professor of Surveying and Land Information* and at a later date the *Dean/Chairman, School for Graduate Studies and Research* at the St. Augustine Campus in Trinidad.

He moved to Australia to join Southern Cross University during January 2007 to become the *Professor of Environmental Geoinformatics and Head, School of Environmental Science and Management.* During August 2009, Professor Baban was appointed to become *Professor* and the *Vice Chancellor* of the University of Kurdistan Hewler. He was appointed competitively by an international panel to this post as a result of the University's global search for a Vice-Chancellor. On April 5th 2012, Professor Serwan Baban was appointed *Minister of Agriculture and Water Resources* in the seventh cabinet of the Kurdistan Regional Government in Iraq.

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Professor Baban's *research interests and accomplishments* are in *Geosciences, Environmental Science, in Geoinformatics (Environmental Remote Sensing and GIS) and in Higher Education and University Governance*. He has a multi-disciplinary Geo-based background and working experience in Arid/Semi Arid (Iraq, Tunisia, Morocco, Jordan and Australia), Temporal (UK) and Tropical environments (Malaysia, the Caribbean region, Indonesia and Australia).

Professor Baban has authored and co-edited twelve books and over 200 research and consultancy publications. These are composed of 101*, refereed journal and conference proceeding publications;* 37*, refereed chapters in books;* 34*, consultancy and special reports and* 63*, other refereed publications, presentations and abstracts.* He has served on the *scientific and organizing committees for various international conferences worldwide* (UK, Holland, Australia, USA, Jordan, Trinidad and Tobago, Barbados, Jamaica, Bahamas, India, China, Thailand and South Africa) and is a *member of the Editorial Board and an academic referee for a wide range of international, regional and national refereed journals*.

Professor Baban *founded and directed several successful research centers and Institutes worldwide.* These include; the *GIS and Remote Sensing Research Utility* (GRRU) group at Coventry University, UK (1992–2000); the *Center for Caribbean Land and Environmental Appraisal Research* (CLEAR) at the University of the West Indies in Trinidad (2000–2007); the Centre for Geoinformatics Research and Environmental Assessment Technology (GREAT) at Southern Cross University in Australia (2007–2009) and finally the *Geoinformatics Institute for Future Threats to Sustainability* (GIFTS) at the University of Kurdistan Hewler (2009–2012).

In terms of international professional involvement, he is a *Fellow of the Royal Geographical Society* (FRGS), *Fellow of the Geological Society* (FGS), *Fellow of the Remote Sensing and Photogrammetry Society* (FRSPSoc), *Fellow of the International Congress of Disaster Management* (FICDM) and a *Visiting Fellow,* School of Environmental Sciences, University of East Anglia, UK.