Rufiji Environment Management Project[1]

Environmental Management and Biodiversity Conservation of Forests Woodlands, and Wetlands of the Rufiji Delta and Floodplain

Research Master Plan for the Rufiji Floodplain and Delta 2003 – 2013

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[1] The Rufiji District Council implements Rufiji Environment Management Project with technical assistance from IUCN – TheWorld Conservation Union, and funding from the Royal Netherlands Embassy.

Rufiji Environment Management Project – REMP

Project Goal
To promote the long-term conservation through 'wise use' of the lower Rufiji forests, woodlands and wetlands, such that biodiversity is conserved, critical ecological functions are maintained, renewable natural resources are used sustainably and the livelihoods of the area's inhabitants are secured and enhanced**.**

Objectives

- To promote the integration of environmental conservation and sustainable development through environmental planning within the Rufiji Delta and Floodplain.

- To promote the sustainable use of natural resources and enhance the livelihoods of local communities by implementing sustainable pilot development activities based on wise use principles.

- To promote awareness of the values of forests, woodlands and wetlands and the importance of wise use at village, district, regional and central government levels, and to influence national policies on natural resource management.

Project Area
The project area is within Rufiji District in the ecosystems affected by the flooding of the river (floodplain and delta), downstream of the Selous Game Reserve and also including several upland forests of special importance.

Project Implementation
The project is run from the district Headquarters in Utete by the Rufiji District Administration through a district Environmental Management Team coordinated by the District Executive Director. The Project Manager is employed by the project and two Technical Advisers are employed by IUCN.
Project partners, particularly NEMC, the Coast Region, RUBADA, The Royal Netherlands Embassy and the Ministry of Natural Resources and Tourism, collaborate formally through their participation in the Project Steering Committee and also informally.

Project Outputs
At the end of the first five –year phase (1998-2003) of the project the expected outputs are:
An Environmental Management Plan: an integrated plan for the management of the ecosystems (forests, woodlands and wetlands) and natural resources of the project area that has been tested and revised so that it can be assured of success - especially through development hand-in-hand with the District council and the people of Rufiji.

Village (or community) Natural Resource Management Plans: These will be produced in pilot villages to facilitate village planning for natural resource management. The project will support the implementation of these plans by researching the legislation, providing training and some support for zoning, mapping and gazettement of reserves.

Established Wise Use Activities: These will consist of the successful sustainable development activities that are being tried and tested with pilot village and communities and are shown to be sustainable

Key forests will be conserved: Forests in Rufiji District that have shown high levels of plant biodiversity, endemism or other valuable biodiversity characteristics will be conserved by gazettement, forest management for conservation, and /or awareness-raising with their traditional owners.

Preface

The present Research Master Plan for the Rufiji Floodplain and Delta was prepared for the Rufiji Environment Management Project (REMP) with the help of researchers and managers in various institutions who gave their views regarding research in the Lower Rufiji. The REMP project is implemented by the Rufiji District Council with technical assistance from IUCN, who are currently working in the lower Rufiji Floodplain and Delta to promote long-term conservation through wise-use of the lower Rufiji forests, woodlands and wetlands in order to conserve biodiversity, maintain critical ecological functions, sustainably use the renewable natural resources and secure and enhance the livelihoods of the area's inhabitants. During July/August 2001, over 40 people with an interest or mandate in the Rufiji were contacted in over 25 institutions, including research institutes and university departments, management and decision-making bodies. Participation and involvement of research institutions and/ or individuals was sought to gather information on their research priorities, capacities, interests, experience, needs and constraints as well as to gather existing information or research outputs from previous research efforts in Rufiji. Management and decision-making institutions (including NGO's and projects) were also visited (1) to seek their input in identifying the needs and priorities for research in meeting management demands for planning and resource use in the Rufiji, and (2) to identify the role research could play in securing the livelihoods of the Rufiji people as well as the long-term sustainability of the resource base for the nation at large, in a way that does not compromise the biodiversity or functioning of the area. In addition, international linkages and funding opportunities that could potentially support applied research in Rufiji were investigated. A discussion paper, summarising the findings was circulated to research, management and development partner communities for comments. Finally, a workshop, bringing together some 48 participants, including elected district council members, heads of department and other district staff, research organisations and individual researchers, and development partners was organised in Dar es Salaam in December 2001. The exchange of views was lively and avenues for research were explored. It is the sincere wish of the author that this research master plan would make a valuable contribution to the environmental management of the Rufiji floodplain and delta.

Dar es Salaam, March 2002.

Acknowledgements

This Master Plan has been developed with the participation of various institutions and individuals. I would like to thank all the members of Rufiji Environment Management Project (REMP) for their cooperation and time during visits. Mr. Fissoo, District Executive Director, is acknowledged for his facilitation of contacts with Rufiji District staff, members of the District Environment Management Team and elected Council members, Dr. Olivier Hamerlynck and Rose Hogan for their support, Barnabas, Albert, the drivers and other REMP personnel for making my work pleasant. I would also like to thank all the individuals who gave me their time for discussions in preparation for the Discussion Paper. These represented various institutions including the Rufiji District technical staff and Council Members, The University of Dar es Salaam, Institute of Marine Science, Zanzibar, Institute of Resource Assessment, University College of Lands and Architectural Studies, Sokoine University, National Tree Seeds Programme, NEMC, TAFORI, TAFIRI, TRAFFIC, COSTECH, TCMP and staff from the Ministry of Natural Resources. I am also indebted to all the participants of the workshop "Towards a Research Master Plan for the Rufiji Floodplain and Delta" for their time and participation in the discussions. Without documentation on past research, a research master plan is pointless. For this I am grateful to the people who made information available by allowing me to borrow literature and other materials particularly RECOSCIX, Mombasa, TRAFFIC, the University of Dar es Salaam library, IRA documentation centre and Heather Hoag for her bibliographic collection. Many thanks to Dr. Paul Erftemeijer for his persistent encouragement and company during some of the visits and also for his comments on the first draft of the master plan. Funding for this exercise and the workshop was made available by the Royal Netherlands Embassy. Finally many thanks to staff at IUCN personnel for their support in various ways, in particular Dr. Jean-Yves Pirot, Geoffrey Howard and Kelly West.

Table of Contents

Abbreviations and acronyms

ASDS	Agricultural Sector Development Strategy
BRALUP	Bureau of Resource Assessment and Land Use Planning (now IRA)
CIFOR	Centre for International Forestry Research
CIRAD	French Scientific Institute for Tropical Agronomy
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
COMREC	Coastal Management Research Centre
COSTECH	Tanzania Commission for Science and Technology
CPU	Catch Per Unit Effort
DANIDA	Danish Development Aid Agency
DDT	a persistent chlorinated organic pesticide
ECOMAMA	Postgraduate training course in Marine Sciences, Belgium
FAO	United Nations Food and Agriculture Organisation
GIS	Geographic Information Systems
ICLARM	International Centre for Living Aquatic Resources Management
ICM	Integrated Coastal Area Management
ICRAF	International Centre for Research in Agro-forestry
IFS	International Foundation for Science
ILRI	International Livestock Research Institute
IMS	Institute of Marine Science
IMWI	International Water Management Institute
IRA	Institute of Resource Assessment
IRD	Institut de Recherche pour le Développement (France)
IUCN	The World Conservation Union
JGOFs	Joint Global Ocean Flux experiment
MARG	
MASMA	Marine Science for Management
NEAP	National Environment Action Plan
NEMC	National Environment Management Council
NGO	Non Governmental Organisation
NTSP	National Tree Seed Programme
PEW	US charitable trust that finances the coastal management awards scheme
PRSP	Poverty Reduction Strategy Paper
RAMSAR	Convention on Wetlands (Ramsar, Iran 1971)
RECOSCIX	Regional Cooperation in Scientific Information Exchange
REMP	Rufiji Environment Management Project
SAREC	Swedish International Agency for Research Cooperation
SIDA	Swedish International Development Agency
SUA	Sokoine University of Agriculture
TAFIRI	Tanzanian Fisheries Research Institute
TAFORI	Tanzania Forestry Research Institute
TANESCO	Tanzania Electricity Company
TCMP	Tanzania Coastal Management Partnership
TEHIP	Tanzania Essential Health Interventions Project
UCLAS	University College of Lands and Architectural Studies
UDSM	University of Dar es Salaam
USAID	United States Agency for International Development
VUB	Free University of Brussels
WIOMSA	Western Indian Ocean Marine Science Association
WREP	Water Resources Engineering Programme
WWF	World Wide Fund for Nature

1 Introduction / Goal

Scientists and resource managers often have different perspectives and imperatives, a disparity which undermines the responsible management of the resource bases that have a wide range of uses and values associated with them. Management of highly valuable natural resources demands that management decisions be based upon the best scientific information available. To the natural resource manager and the scientist, time may seem to be rapidly running out for many tropical ecosystems. Unequivocal acceptance of industrial growth and expansion has brought the world to a threshold in the Earth's ability to absorb pollution and in the exploitation of its scarce resources. Yet our ability to affect the environment is matched by our inability to assess the consequences of our actions, as we come to realise that natural and human processes are inextricably intertwined. To what extent we don't know. A consensus needs to be forged on reconciling development and environmental quality and this requires competent environmental management on a global scale, which means national, regional and community scales as well. It is clear that the management of complex ecosystems subject to significant human pressures cannot be adequate in the absence of support from both natural and social science. If scientific information generated is to be relevant and properly applied for management purposes, scientists and managers must work together as a team.

All this suggests that environmental management is about far more than biophysical manipulation and control (engineering structures and technological fixing). Environmental management activities are recently taking up the challenge to widen the focus of natural resource management to include the systems that support resources and the human dimension. Without understanding of the human interactions in global environmental change, based both on empirical observations of human behaviour and on a better understanding of the consequences of human interactions, the models of physical and biological processes of change will be incomplete.

Yet the environmental challenges are multiple and complex. Multiple in the sense that environmental systems and subsystems, with their own dynamics, continuously interact and change, leading to uncertainty about environmental phenomena. Complex because the wide range of causal factors involves a combination of socio-economic and societal issues as well as environmental ones. Different perceptions and different states of knowledge contribute to a confused and limited understanding of environmental processes. In the foregoing, both the need for a research agenda for supporting management as well as the need for collaboration between researchers and managers in order to develop programmes that will reach agreements on the scientific work needed to address priorities and guide policy, cannot be overemphasised. This is the need for action to establish ways of identifying and filling key data gaps and to ensure that available data are presented clearly and analysed thoroughly, recognising problems which exist when reductionist and partial, selective or sectoral analysis occurs. The natural sciences are vital to understanding the functioning of ecosystems and the social sciences are essential to comprehending patterns of human behaviour that cause ecological damage and to finding effective solutions, i.e. to give guidance on how to bring about changes in behaviour.

In Tanzania, some initiatives such as the adoption of Integrated Coastal Area Management (ICM), Lake Victoria Environmental Management Project, Tanga Coastal Zone Management Project and the Rufiji Environment Management Project have similar goals of conserving the productivity and biological diversity of ecosystems while improving and sustaining the quality of life of human communities. These initiatives have provided forums for interdisciplinary, cross-sectoral consideration of research and resource use planning and are bringing a fresh outlook to natural resource development.

The Rufiji River Basin in southern Tanzania is the largest in the country and the most important for many activities, goods and services associated with water and its uses. The Rufiji River, draining over 20 % of the country, contains the largest low level floodplain (1450 km^2) in Tanzania, while the delta (1400 km^2) has the largest area of mangrove (532 km^2) in East Africa. The lower Rufiji floodplain and delta have been identified as one of the most important wetland areas in East Africa,

owing to their rich biodiversity and high productivity. As with many rivers in Africa, the Rufiji is subject to highly variable rainfall and flooding. These occasionally take on catastrophic proportions but in general fuel the high productivity and provide valuable resources to the inhabitants and the country at large. A recent book on ecological history of Tanzania suggests that it used to be one of the country's most fertile and prosperous regions (Kjekshus, 1977). Over the last decades however, the Rufiji forests, woodlands and wetlands have come under increasing pressure with various unsustainable off-take rates of exploitation, while the 150,000 inhabitants are among the poorest in the country.

The identification of research priorities to support management of such a large and complex area is not a trivial task. In the development of this research strategy, a participatory approach was followed in which government agencies and scientists from various institutions were consulted for their views on the area. A series of interactive workshops were held aimed at determining high priority management issues (two stakeholder workshops) and the information needs required to address those issues (one research planning workshop). It is hoped that this research master plan will act as a blue print for short- and long-term research-for-management activities in the area. Its goal is to provide the Rufiji District, the national and international scientific community, the inhabitants of the Rufiji floodplain, delta, woodlands and forests and the development partners with a coherent research programme aimed at understanding the physical, biological and social processes that drive the functioning of its vital ecosystems. The approach preferred being holistic, thematic rather than the traditional sectoral, single disciplinary style. Its implementation is a precondition for the development of effective management measures targeted at maintaining or restoring the various ecosystems and their biodiversity and ensuring the sustainable use of natural resources.

2 The need for research and monitoring

The Rufiji floodplain, delta, woodlands and forests are subject to increasing levels of exploitation of the natural resources, with various unsustainable off-take rates. Despite their national and international importance, the Rufiji floodplain and delta have received little scientific attention to date in comparison to other areas in Tanzania. The biodiversity, the dynamics of the component ecosystems and the socio-economic conditions of the people, their land use activities and their degree of dependence on the natural resources of the ecosystems are poorly understood. Emphasis by development partners is being put on direct poverty relief of the rural communities with the implication that donor agencies are reluctant to fund the interdisciplinary research essential to the development of effective management plans addressing sustainable use of resources.

Many of the vital ecosystems in the Rufiji are overexploited or subject to unsustainable harvesting. This is especially true with regard to harvesting of hardwood species, conversion of forest and woodland for dryland agriculture and cash crops, conversion of mangrove for agriculture and overexploitation of its woody biomass for other purposes, damage to coral reefs by destructive fishing techniques, live coral extraction for lime production and over-harvesting of species such as sea cucumbers, over-fishing and use of fine meshed nets in lakes and rivers, hunting of birds and mammals, etc. New developments such as shrimp farming, tourism, professional hunting, large-scale irrigated agriculture, the expansion of livestock keeping, roads and other infrastructure developments, oil and gas exploration, etc. may pose further challenges to the ecosystems. On the other hand, the local communities make economic choices from a complex range of options that are offered by an equally complex set of dynamic ecological conditions. At present, only a very limited and largely unisectoral understanding of the lifestyles and livelihood security options exists. Coping strategies that impact optimally on the natural resource base need to be researched. Cultural and historical influences on present attitudes to, and decisions regarding the management of natural resources are not documented in a comprehensive fashion. Trends in population size, emigration and immigration and movements within the district are not well characterised. Trading in and marketing of natural resources appears to be increasingly focussed on volume expansion rather than on increasing added value. Trade routes and marketing chains need to be well described in order to be able to propose improved options for both the sustainability and profitability of the resource use. In the medium to long term the changes in the river flow through increased abstraction upstream and the building of hydropower dams will almost certainly affect the ecosystems that are flood dependent, either through submersion or through groundwater recharge. Infrastructure development, social change, shifts in the national policies and economic strategies are increasingly affecting livelihoods in Rufiji District. Temporal trends due to regional or global changes (climate change, sea level rise, and increased frequency of extreme climatic events) may start to have measurable impacts.

It is clear from the foregoing that there are complex issues and multiple forces involved, which complicate the environmental management process in Rufiji. There is the environmental challenge, which includes the multiformity of environmental systems and subsystems with their own dynamics, continuous interaction and changes. These lead to uncertainty about environmental phenomena. Different states of knowledge and different perceptions contribute to the limited understanding of the environmental processes. Moreover, there is the range of causal factors in relation to environmental problems to deal with, and this further increases complexity because they involve a combination of socio-economic and societal issues as well as environmental ones.

Therefore, apart from studying the environmental characteristics and the impacts of human action, research is required to look at, socio-economic and structural (the socio-political context within which environmental management takes place) aspects of causality of environmental problems. It does not necessarily have to be weak legislation or low fines, but might in fact be poverty and economic insecurity, which encourage the present overexploitation of natural resources and population growth. Research may also address the ways in which socio-economic change can solve or diminish the problem. This is necessary because action to address economic insecurity may have to precede the discussion of environmental management issues. For instance, meeting the

immediate fuel needs for cooking can be a priority over forest protection (where threat to forests is fuelwood). There is more to environmental analysis than the gathering of data locally because causal factors operate at a variety of scales from the very local to the international and they overlap and interact.

With this understanding, Rufiji Environment Management Project's (REMP's) goal is to promote long-term conservation through wise-use of the lower Rufiji forests, woodlands and wetlands in order to conserve biodiversity, maintain critical ecological functions, sustainably use the renewable natural resources and secure and enhance the livelihoods of the area's inhabitants.

One of the ways to meet these goals is through environmental planning (district environmental management plan, community natural resources management plan, wise use activities, forest conservation and biodiversity documentation, updating and revising relevant policies) and creating awareness of the values of forests, woodlands and the wetlands of the area. However, environmental planning also requires appropriate information of high quality in order to:

(i) Understand the ecology, biodiversity and functioning of the ecosystems and appreciate the total economic value of the resources and ecosystems (including existence, option and use values)

(ii) Understand the level of use of the resources (socio-economics) of different areas in relation to seasons, rainfall and floods (hydrology)

(iii) Identify ways in which the sustainable use of Rufiji's resources can be achieved and maintained by local communities, considering the changing economic, demographic and policy conditions, which exacerbate land use pressures, and how these pressures can be reduced. This should include identifying key characteristics/indicators of sustainable resource utilisation, developing monitoring methods and disseminating the information.

(iv) Gather baseline data and monitor future changes

(v) Develop and adopt management practices to ensure sustainability

(vi) Comply with the obligations attached to international environmental conventions (e.g. CITES, Biodiversity, Ramsar, Climate Change)

(vii) Address links between poverty and environment

Too often such information needs are not met because of irrelevant or inappropriate research. Research identified and applied in this context often seeks to fill the knowledge gaps in management questions, but does not address the need for improving or changing management procedures. Research should generate data that is required to draw conclusions on the pressing issues in the area (and in this manner facilitate the emergence of appropriate management decisions to address these).

Environmental planning and environmental management are relatively new fields, which are moving away from the traditional approach to development planning and single sector reviews. The Rufiji floodplain and Delta are influenced by fairly irregular floods, which make environmental planning a difficult task. Short-, medium- and long-term research in biophysical (carrying capacity) and social sciences, economics, historical studies, soil science, land tenure, crop sciences, food and nutritional studies, rural development, administration, demography, business and marketing, anthropology etc.) is therefore necessary. This research master plan has been developed to bring to the limelight the urgent need for informed, integrated, interdisciplinary research that should contribute to addressing resource and environmental management issues.

3 Guiding principles for strategic research planning in Rufiji

3.1 Integrated, Interdisciplinary Research

The question of how much economic growth can be sustainable is challenging especially given the reasonable aspirations of lower income countries such as Tanzania to higher levels of economic growth and the obvious material benefits that come with it. The challenge facing managers in Rufiji is how to adapt the economic activities to the carrying capacity of the ecosystems. Faced with multiple issues in achieving management objectives, the need for an integrated, interdisciplinary research approach is apparent.

This Research Master Plan proposes integrated research, which implies the integration at different levels, firstly between the scientific fields and disciplines and secondly between the theoretically based academic work and the level of practitioners. Rather than following a classical discipline by discipline approach, the focus of the research priority needs addressed in this master plan (i) directs attention to the values, potential impacts, resource use (planning and decision making) and monitoring; and (ii) relies as much on biophysical as on socio-economic, cultural and political elements of environmental issues. Although it is acknowledged that such a challenge is inclined to be confronted with a range of difficulties. It needs mechanisms to overcome both cultural cleavages between, on the one hand different academic disciplines and between academic cultures and those of the practical life on the other. Integrated assessments provide an effective format for bridging science and policy and, therefore, they are the appropriate context for designing a research and monitoring strategy.

Environmental management is a much wider and more fundamental activity than natural resources management. Natural resources are part and only part of environmental systems. To focus research on natural resource management alone is to cover only a particular product or a range of products, the management objectives of which are limited, with increased yields or profitability commonly dominating. Such a narrow focus has often led to damage to the wider environmental systems that support resources. A key component of such systems is the ability to absorb pressures and new inputs up to, but not beyond, certain limits of tolerance. Such thresholds are too often passed as a result of natural resource management's narrow perspective that leads to unsustainable practices and environmental damage. This Research Master Plan for the Lower Rufiji Valley has been developed with a focus on issues affecting the environment where natural resource use is a component of the environment.

For this reason the master plan includes research that supports core environmental management activities that are devoted to avoiding, mitigating and remedying actions that are damaging to the very support systems that natural resources rely on. A holistic viewpoint is essential, not only of human nature and social organisation, but also of individual aspects of biophysical components of the physical environment. Therefore research should lead to the understanding of the processes of environmental change and the reasons for these. The emphasis, therefore, should not only be on the innate characteristics of aspects of the environment, but rather on their health or status, the pressures upon them, and the dynamics of the observed change. In this regard the research plan will underscore the need for data that relates to:

- Status – in terms of measures of specific phenomena (e.g. levels of land based inputs to the sea, carrying capacity, water requirements for the survival of ecosystems, etc);
- Stocks – in terms of quantity of environmentally provided assets such as forests, wildlife, fisheries, water, wetlands, soil, atmosphere. These provide a flow of useful goods or services;
- Flows – which include materials, and elements through the system (pollutants, DDT, nutrients, water, sediments, plant and animal biomass…). The flow of perceived benefits involves the notion of value. Each of these facets may be considered in a range of ways, for example, in absolute terms, or relatively, or by reference to specified standards or economic value;

- Interventions into the system – impact of biological, chemical and physical changes on ecosystems, ecosystem components and people.

In developing the plan, a process-oriented approach was taken, which embraced building of partnerships to answer research questions and constitute the basis for research in support of environmental management in the district. These partnerships should attempt to generate information as well as incorporate the views of Rufiji District's stakeholders in identifying management issues. Integrated, interdisciplinary research is not synonymous with multidisciplinary research that leads to separate studies by scholars of different disciplines on the same object of study without much cooperation or integration. Rather, its added value is higher than the sum of the latter. It is an applied approach where the focus of study is clearly defined and is related to different disciplinary work tasks. For instance, what would happen if the floodplain/delta receives too much or too little flooding? Approaching this issue in an interdisciplinary context will be different from commissioning hydrologists and engineers to study the issue and the provide information on the basis of which the decision-makers will decide. The plan accounts for interrelationships and interdependencies between studies.

3.2 Research phased over time

Without careful planning and proper co-ordination, research and monitoring can dissipate large amounts of money while failing to provide the information that is most needed for environmental management. Relevant and cost-effective information is most likely to result from studies that are initiated as part of a well integrated programme which will encompass basic and applied research, monitoring (i.e. repetitive measurements using validated methods) and periodic assessments of environmental quality. This Research Master Plan will be phased over time to address several of the major attributes of integrated research and monitoring.

- Short-term and applied research to support urgent conservation measures. This should involve characterisation of the problem;
- Medium-term research to support planning and development. This should involve diagnosis of the causes of the problems;
- Long-term and fundamental research to support understanding of intricate ecological processes, a key to defining sustainability. This should involve diagnosis of interactions and forecasting so that together with medium-term studies it will provide an understanding of the relevance of a particular relationship or issue.

3.3 Research aimed at defining indicators and monitoring measures

The scientific programme ensures that activities in research and monitoring are, as far as possible, complementary. As a general rule, all monitoring should be preceded by research to develop suitable methodologies, to clearly establish the conditions under which the methodologies can be usefully applied and to verify their suitability for routine application. An important aspect of this is to ensure that enough knowledge exists to allow the results from monitoring to be reliably interpreted. This requires thorough understanding of the causes and extent of variability (both temporal and spatial) in the variables to be monitored.

The lack of indicators that link poverty and environment deserves to be mentioned here as poverty is probably one of the major driving forces of unsustainable management practices in the Lower Rufiji. In the events of environmental degradation, poorer people are more susceptible to health risks due to lower ability to respond. They are more vulnerable to changes in the environment because they are more dependent on natural resources. Environment can be directly linked to poverty in that environmental degradation reduces the opportunities for livelihoods based on natural resources such as food, fodder, fuel, medicines etc. Indicators that link poverty and environment may include but not be restricted to forest loss, water quality, child stunting, and household consumption. The master plan points to research that comes in to help meet the challenges that face the link between poverty and environment and to studies that could be commissioned to look at existing indicators especially for specific activities aimed at poverty alleviation. The approach should not lump all indicators, but choose a few and after interventions,

try to quantify the effects on that indicator. Areas of overlap should be identified (between high poverty and high degradation). Subsequently, monitoring should be undertaken in those areas, while retaining national level indicators. Monitoring can only occur when indicators are identified at various levels (community or village, district and national).

Scientists should also have a role to play in the programme evaluation process. They should evaluate the relevance, reliability and cost-effectiveness of the scientific information generated by research and monitoring and advise on the suitability of control data. Estimates should be provided of the extent to which certain observed changes can be attributed to the management measures implemented or to other factors.

3.4 Research leading to clear management decisions

Competent management of complex systems such as are found in the Lower Rufiji, which are at the same time subject to significant human pressure, cannot occur in the absence of good scientific information. Science must therefore be undertaken within a structure of solving problems, using an issue-driven approach. Data collection needs to be specific and relevant to the problems. However, in the absence of arrangements to provide incentives to the scientific community to focus its research on management issues, scientists might not address directly the questions for which managers seek answers. Scientists should work with managers to prepare concise statements of objectives for research and monitoring, clearly defining what is to be measured and why, and identify methodologies, facilities and personnel needed for the studies to be cost-effective and successful. Research should help management by measuring degradation, whether due to human impacts or natural perturbations or both. This may require experimentation and interpretation, and because of possible subjectivity, precaution and proper use of techniques developed for assessing impacts is essential.

Economics are more important, to some segments of the public, in justifying conservation measures than ecology. Long-term benefits to society in terms of maintained harvests, employment and recreation are obvious, but few studies have calculated these in economic terms, which can be directly compared with the value of short-term over-exploitation. Economic valuation of the goods and services provided by the Lower Rufiji environment therefore figures prominently in the research plan.

In the attempt to collect, analyse and present quantitative information it is imperative that researchers realise that knowledge has two components – information and familiarity. Knowledge of the environment depends not only on the available data but also on our perception of it. What makes environmental data useful to managers involves the aspects of (1) quality and accuracy of data (2) managers' perception and understanding of the environmental situation and causal processes, and (3) the managers' ability to interpret the quantity of data and environmental diversity. Therefore, research aiming at increasing availability and quality of data should be aware of pitfalls such as:

- partial coverage in terms of subject matter
- limited areal and temporal coverage and thus limited representativeness of the data
- poor quality of data due to inaccuracy of measurement and recording.

Hence, the science and practice of statistics should be applied and results should preferably be presented as maps and graphics, which carry so much more meaning in very convenient shorthand. Provided that statistical methods are used with care and with critical understanding, they can be very powerful tools. Quantitative figures (e.g. the volume and rate of resource use and the revenue accrued from these resources) clearly relay to managers what is at stake.

Research ought to be detailed enough to answer management questions. Thus studies that quantify issues are more desirable in this regard than qualitative ones. Finally, in order for research to lead to clear management decisions, research agendas should include the mechanisms for building communication between researchers and managers.

4 Context and history of the Lower Rufiji

4.1 The Lower Rufiji Valley

The lower Rufiji valley starts downstream from Stiegler's Gorge, some 180 km from the Indian Ocean, in the Selous Game Reserve. Below the gorge the river fans out in an inner delta with numerous lakes and subsequently enters its lower floodplain, which gradually widens until the river branches out and forms the Rufiji Delta. The floodplain, which covers approximately 1450 km², comprises a mosaic of former river channels, levees and shallow depressions supporting sparse shrub, intensive cultivation (mainly rice), scattered treecrops (mango, banana) or tall grassland. The floodplain also has palm (*Borassus*, *Hyphaene* and *Phoenix*) and *Acacia* woodland while riparian forest is found on the higher riverbanks. There is also riparian/groundwater forest around the edges of a series of lakes that are connected to the river during the annual floods. The large floodplain lakes in the Lower Rufiji valley occupy roughly 2850 ha (or 56 %) of the surface of standing water bodies in the valley (Mwalyosi, 1990). The higher ground North of the floodplain is covered by a woodland/coastal forest mosaic. To the south of the river are a series of hills with important forested areas, dense woodlands and coastal shrub (often referred to as "thicket"). The Rufiji delta on the other hand contains the largest area of estuarine mangrove in East Africa (approx. 532 km² in 1990 but increasingly cleared for rice farming). The deltaic plain formed at the Indian Ocean by the Rufiji river is approximately 23 km wide and 70 km long (Chen and Dyke, 1998). The wealth of natural resources in this area supports the livelihoods of some 150,000 people. The lower Rufiji and delta area has been identified as one of the most important wetland areas in East Africa, owing to its rich biodiversity and its high productivity (WWF, 2001) and at a recent World Heritage site workshop, the Rufiji Delta - Mafia Island - Songo Songo Archipelago complex was listed as a tropical marine and coastal ecosystem of Outstanding Universal Value (OUV) with the highest priority for listing as a World Heritage site (Marine Biodiversity Workshop: Filling Critical Gaps and Promoting Multi-Site Approaches to New Nominations of Tropical Coastal, Marine and Small Island Ecosystems" Hanoi, Vietnam, 25 February to 1 March, 2002).

4.1.1 Agriculture in the Rufiji flood plain - past and present situation

In addition to the normal rain-fed agriculture, a bonus harvest from the so-called *mlao* cultivation exploits the recharged water table in the floodplain following the annual floods. This cultivation is independent of local rainfall and does not require clearing. The rich alluvial deposits of the lower Rufiji valley stretch approximately one hundred miles (km?) upstream from the delta. As described by Elton (1879) - in the previous centuries, the fertility of the lands lying between the Mohoro and Rufiji rivers was extraordinary. Maize, rice, millet, groundnuts and peas were largely cultivated, and heavy crops were garnered every year, the periodical inundation bringing fresh life to the soil. Sheep, cattle and goats were present in sufficient numbers to be bought for export and shipped at either Murengu or Somanga. It appears that this was a land of plenty. Ziegenhorn (1896) recorded the export of large quantities of foodstuffs (beans, maize, rice, and sesame seeds) from the Rufiji villages to Zanzibar. His review indicated relatively heavy population concentrations near the fertile floodplains where the main villages were located. Indigenous food demands must have been considerable. The agricultural production in most villages aimed, however, beyond self-sufficiency to create considerable surplus for export outside tribal boundaries. Because of the important rice exports, the area was referred to as "*Calcutta Mdogo*" – Little Calcutta (DKB 1893).

Agriculture is the main occupation (93 % of households) in the Rufiji floodplain and delta. It is the most labour intensive activity but not necessarily the highest contributor of income. Today a total of 58, 500 ha (10 % of the terrestrial area) is estimated to be cultivated land including fallow areas with a period of ≤ 3.5 years. This includes total cultivated area in the floodplain (52 %), transition (32 %) and delta (16 %) eco-regions (Turpie 2000). At least 24 types of crops are grown, with rice, the staple food, being grown by 76 % of the households in the Lower Rufiji Valley. Rice, maize, sweet potatoes, millet, vegetables and fruits are largely grown for subsistence, but with a proportion being sold for cash income. Cash crops make up less than 10 % of the net economic value (Turpie, 2000). The likelihood of agricultural losses of more than half (> 50%) the yield is not uncommon. Vermin, drought or excessive floods (caused by the unpredictable flooding regime)

are the reasons given for crop losses. Good floods, however, are also still the main reason for bumper crops. This leaves the general picture of inadequate harvest that results in rampant food shortages throughout the floodplain and delta (Hogan *et al.*, 2000). No exports are reported today from the area while families mainly use the proceeds from a bumper harvest or surplus to buy food and clothes. Food therefore remains the main expenditure item because quantities of food crops produced are not adequate to cover all the household needs of food and cash. In contrast to the previous "*Calcutta mdogo*", crop production in Rufiji is now generally considered to be below the available potential (DANIDA 1998). During the villagization campaigns (1969 and 1973), people were moved to drier areas away from the floodplain. Though they experience less risk from floods in those areas, they cultivate less fertile land and are entirely dependent on rainfall. The *shambas* on cleared woodland and forest are therefore abandoned after a few years and "shifting cultivation" is now a common type of farming. Traditionally, different tribes were cultivating the floodplain and the drylands and, through 'joking' relationships (reference, see Shipton paper) there would be a buffering system against failed harvests. In years of good floods, the floodplain would feed the hills, in years of poor harvest on the floodplain, the hills would feed the floodplain. These relationships have broken down and, in any case, population densities are now so high that the fallow periods on the drylands have become shortened. Increasingly, marginal land is being cultivated, e.g. on slopes and in proximity to water bodies and primary forest and woodland are dwindling fast. The biodiversity impacts are considerable and much of the land, cleared and cultivated in ever earlier regeneration stages, is degrading.

4.1.2 Agriculture in the delta islands

In the past the inhabitants of the delta had their rice fields in the floodplains upstream from the mangrove areas. They would migrate there during the agricultural season. After the harvest they returned to their villages on the islands mostly for fishing and for the exploitation of the mangrove, predominantly for poles exported to Zanzibar and beyond. During the villagization campaigns everyone was moved out of the floodplains, and the *Wanyagatwa* took up permanent residence on their deltaic islands. They had to find alternative sites for agricultural production. They started clearing certain types of mangrove forest that were not permanently flooded by salt water for rice cultivation. This type of agriculture is also flood dependent and in low flood years increased salinity hampers production. When the rice shoots are young they are attacked by the numerous crabs residing in the mangrove and various pesticides are used to eliminate those. The mangrove *shambas* are abandoned after a few years because of colonisation by weeds. Usually mangrove does not regenerate spontaneously in those areas. Clearing of mangrove for rice cultivation is still expanding and increasingly practiced also by non-residents of the delta proper, mainly from mainland villages such as Ruaruke and Kikale. This threatens the survival of certain types of mangrove forest, such as stands dominated by *Heritiera littoralis* and mixed *Avicennia marina-Ceriops tagal* stands.

Data on agricultural production in the mangrove is scarce. However, according to Von Mitzlaff (1989) it seems a good harvest will feed a family over the year and might also give them some additional income. The year is divided into the agricultural season when a family lives in the fields in "*dungus*", which is a house that overlooks the fields, built on poles about 3 metres high, and the other season when they live in the village. After the harvests are brought into the village, the fields are abandoned. Nothing but rice is grown in the fields. A handful of people has small gardens near their houses where cassava (for its leaves) and sweet potatoes are grown. Maize is bought if the harvest is not sufficient. A few families have fields on the mainland with the advantage of having a greater variety of food. Unfavourable weather conditions (low floods), insufficient family labour, vermin and exhausted fields are the reasons given for bad results that force people to buy staple food.

4.1.3 Flood characteristics of the lower Rufiji

Flood regimes in the Lower Rufiji have shown considerable variation in the past and records of floods that have impacted on humans exist from the 19th century. One of such floods caused the river to change its course from the northern edge to the southern edge of the valley in1875, in the

region north of Utete (Savile, 1945). Another such flood, which caused a second change of course in the same region, is said to have occurred just after the German occupation of this area in about 1890. Up to 1945 the largest flood in living memory occurred in 1917, the previous flood being in 1905 and succeeding major floods being those of 1930, 1936, 1942, 1944 and 1945. A detailed study of the river's behaviour made in 1937 (reference) indicated that the time lag between up-country rainfall and the reaction of the river to such rainfall varied between 2 – 12 days depending on the sub-basin (Luwego, Kilombero, Ruaha). However, prediction of the river's behaviour cannot be made with accuracy, using only rainfall data, because it depends more on the duration of the up-country rainfall than on total precipitation.
Under the flood regimes prior to 1935 the loss of main crops from abnormal floods appeared to occur on an average of once every 12-15 years. However, such losses were largely offset by the regularity with which high yields were obtained during the remaining seasons. However, this assumption lost hold when in the years between 1942 and 1945 damaging floods occurred five times. The old flood regime had been replaced by alternating years of heavy and medium floods. The underlying causes were concluded to be an increased rate of surface run-off, rather than a cycle of years of high rainfall (Savile, 1945).

Information on flood regimes of the Rufiji between these years and the 70s could not be obtained. However, it is known that the river used to flow directly eastward from Kidai ferry to Mloka, a distance of approximately 40km. During the 1970-71 flood, the river broke through its northern banks approximately 10 km below Kidai to run in a northeasterly direction, thus linking up with the channel of the river Gumba to the southeast of Lake Manze. The flow was then diverted eastward and southward down the course of the Gumba, past Lakes Nzera Kera and Siwandu, to reunite with the main Rufiji channel at Mloka. Thus over the past century the main channel has undergone many changes whereby heavy floods have curved out new channels, old river courses have been blocked, sandbanks have formed and caused deviations while areas once on the north bank are now on the south and vice versa (Kajia, 2000).

Areas of floodplain extend into the floodplain-delta transition area (inner delta). The changes in flow patterns have also affected the areas suitable for agriculture, as these are dependent on spring tidal surges which flood the fields with freshwater. The annual floods of the Rufiji River bring fresh water out into the delta and lower the salinity in the channels. The shifts in predominant outflow channels is claimed to have affected mangrove areas as well (Havnevik, 1993).

At present, the water level in the river varies up to about 6 m between dry and wet seasons, but the relation between rainfall in the catchment area and the extent of floods in the floodplains is little understood, and, because of the collapse of weather and water monitoring systems over the past decades, there is a lack of data from which flood frequency and intensity can be predicted.

4.2 Research in the Lower Rufiji - a historical account

A bibliography prepared as part of the effort to develop the research master plan for the Lower Rufiji valley lists a total of 158 documents dealing specifically with the Rufiji river basin, including 12 scientific articles, 7 environmental impact assessments, 25 recent technical reports by REMP, and 113 other documents.

Chronologically one can distinguish several phases in publications concerning Rufiji. First descriptions of the East African coast, some of which may refer to Rufiji, date back to classical Greek and Arab writers, followed by the Portuguese. Interesting though these may be, they can hardly be classified as research papers. The scramble for colonies in Africa during the late 19th Century brings new impetus to publications on Rufiji and, especially in the Tanganyika Notes and Records Series. Most are travel accounts or anecdotal records. Substantial research efforts in the Rufiji River basin were initiated in the 1970s in response to efforts to explore the potential for a multipurpose dam project at Stiegler's Gorge and to the predictions by FAO of the agricultural potential in the floodplains. Increased environmental awareness in donor countries spawned the studies leading up to the mangrove management plan (Semesi, 1991) and the scope of these kind of

integrated studies with an environmental management drive has been widened to cover the floodplain, forests and woodlands of the Lower Rufiji valley. In general, the bibliography consists of documents that vary greatly in quality, are poorly accessible and scattered over a large number of institutional or personal libraries and archives.

Roughly 30 % of documentation on Rufiji are related to the Stiegler's Gorge. The 7 environmental impact assessment reports addressed the impacts of a proposed shrimp farm development scheme in the Rufiji delta, a proposed multi-purpose dam at Stiegler's Gorge, the development of a bridge across the Rufiji river, the Dar-Mtwara road development, and the proposed Songo-Songo gas pipeline. Although varying in quality, these EIA reports provide an overview of information on several socio-economic, physical and environmental aspects of Rufiji that existed at the time when they were drafted. They are however limited in scope to the specific projects the EIA's addressed. REMP reports mainly deal with studies on socio-economics including the use and value of natural resources, biodiversity, inventories on timber resources, and a preliminary flood-warning model and land use maps produced from a 1999 aerial survey. The other reports cover a range of topics including land-suitability studies for agriculture, hydrology, rice farming, socio-economics, forests and *miombo* woodlands, coastal enterprises, etc..

4.2.1 Hydrology

There are few reliable data prior to 1926 regarding the flooding of the river. Few documents deal specifically with the hydrology of the Rufiji River and the inundations on its floodplain. Firstly, there are a few historical records on the flood regime of the Rufiji. Savile (1945) presented arguments on alterations in the flood regimes of the Rufiji River. In the FAO report (series?), Otnes (1960) documented aspects of the hydrology and water resources in the Rufiji Basin. Information on the hydrodynamics and physical processes (such as currents, tides, salinity, sediment transport, river discharge) in the Rufiji Delta are described in two case studies by Frontier-Tanzania (Elliot Giles, 1993; Fisher, 1994), and in Francis (1992), Temple and Sandberg, (1973) and Tesaker (1979). Havnevik (1993) has written a book about the Rufiji District, which provides a valuable historical background, as well as detailed information about the flood regimes of the Rufiji River. Havnevik's fieldwork in the early 70s also describes the crafts and other non-agricultural activities of the people in the district (Havnevik, 1978, 1980, 1983). The EIA reports and feasibility studies on the proposed Stiegler's Gorge project contain substantial hydrological data pertaining to river discharge, flows and flood frequency. A mathematical model for the Rufiji River open channel flow is described in Shayo (1979). A preliminary flood-warning model was developed recently (WREP, 2002), but further modelling work needs to be done focussed on improving the understanding between the hydrological behaviour of the river, habitat characteristics and ecosystem functioning. The hydrology of the floodplain associated lakes has only recently been addressed through a preliminary study (Pijnappel 2002).

4.2.2 Socio-economics

In the late 1970s and early 1980s studies carried out in the context of the Stiegler's Gorge Dam development potential included some socio-economic studies (Atkins Land and Water Management, 1980, Havnevik, 1983). More recent socio-economic information on the Rufiji floodplain and delta, including the use and value of natural resources, has been collected and documented in REMP Technical reports (Hogan et al., 2000; Kaale et al. 2000; Mbiha and Senkondo, 2001 and Turpie, 2000). These have dealt with fuelwood and charcoal uses, and the general socio-economic profiles, which include economic activities, use of surplus, coping strategies, dependence on and value of natural resources to the local population (and to Tanzania as a whole) and opinions regarding the environment. Turpie, (2000) also investigated some of the economic and other factors that determine household resource use strategies, some of which may affect ecosystem functions and therefore compromise the future value of the area's natural resources. A Rufiji demographic surveillance focussed on health is currently being undertaken by TEHIP. It emphasizes the disease burden in various poverty quintiles but their surveys concentrate on the dryland agricultural areas north of the river and Ikwiriri town. A community profile, published as a compendium to the national mangrove management plan of Tanzania includes a

specific chapter on coastal communities in the Rufiji Delta and their use of the mangrove resources (Von Mitzlaff (1989). Fotland and Sorensen (1996) reported on the socio-economic issues related to the proposed establishment of prawn farms in the Rufiji Delta. Quite comprehensively, Sorensen (1998) describes the way in which people in the Rufiji Delta live and use their resources and shows how they manage and optimise on fluctuating resources.

4.2.3 Agriculture

Early notes mainly based on observations and records of agricultural extension officers included *mlao* cultivation in the Rufiji Valley (Grant 1938a), impacts of floods on crops, rice and cotton ritual and resistance. Land suitability in the Rufiji Basin for agriculture, based on a survey of rainfall, flooding and soil characteristics, was documented in a series of FAO reports and maps in the early 1960s. A case study of the Lower Rufiji soils was also carried out by Cook (1979). Lema (1979) documented the crop water requirements and beneficial flooding for the Rufiji floodplain agriculture while another study by BRALUP reported the impact of rainfall, floods and settlement of Rufiji's agricultural system (Bantje, 1979). Agrar-Und Hydrotechnik (1981) reported on the pre-feasibility of irrigated agricultural development and also studied the potential for improved rain-fed agriculture on the floodplain as an alternative. Nindi (1991) described Tanzanian development ideology and main economic activities, and by explaining economic decline, gave a brief description of Rufiji District as having experienced a shift from cashew nut to charcoal production. He further examined the dynamics of the state-peasant-commercial relationship in Rufiji District within a wider context. In general the author sought to show that the notion of African agricultural "crisis" must be subject to a careful, specific, and historically sensitive analysis. Only recently has rice farming in the delta and its effects on the mangrove forests of the delta been documented (Kajia, 2000). REMP recently commissioned a study on tree crops, small-scale farmers and conservation (REMP, 2001).

4.2.4 Fisheries

Prior to the proposal of a large-scale industrial shrimp farm development scheme in the Rufiji delta - first in the early 70s by World Bank and later in mid 90s by a private developer - little documentation on fisheries can be traced. As a matter of fact, even the most basic data on fisheries in the floodplain and delta is wanting. However, some information was generated stemming from the proposals as part of EIA studies commissioned by different agencies. Owing to the controversial nature of the second proposal, a total of three EIAs, which carry a comprehensive amount of information, can be traced together with other documentation from public hearing comments, media releases and press reports. In addition, Fotland and Sorensen (1996) documented issues on shrimp farming in the Rufiji Delta, while general productivity of crustacean resources were studied by Subramanian (1981), Mahika (1989) and Nhwani et al. (1993). Gibbon (1996) described the prawn fishing industry in Tanzania, including the Rufiji Delta prawn fishery. Gibbon (1997) also presented the findings of research on three principal areas of prawn fishing in Tanzania including trawler and artisanal fishing off and in the Rufiji Delta. He analysed the organisation of production, collection, processing and marketing/distribution in the various prawn commodity chains, in terms of the characteristics and linkages of different forms of enterprise and their agents. The author related the findings of the study to relevant theoretical debates about production forms and markets in African farming and fisheries, including the sources, mechanisms and effects of market power in food commodity chains; forms of enterprise development and accumulation in Africa; and issues of globalization in food commodity chains.

The proposed Stieglers' Gorge dam project also led to some studies on fisheries resources of the lower Rufiji as well as the reservoirs. Such studies included an assessment of fisheries in the Stiegler's Gorge Reservoir (Atkins Land and Water Management, 1981); biology and socio-economic aspects in the proposed reservoir and the delta areas (Atkins Land and water Management, 1980); general fisheries of the reservoir, delta, and Mafia Channel (Atkins Land and Water Management, 1981) and freshwater fisheries on the Lower Rufiji River, including the Delta, in relation to potential modifications by the Stiegler's Gorge Dam (Dorsey, 1979).

In the period leading to the designation of Mafia Island Marine Park, general surveys on coastal natural resources (including fisheries) were carried out. The area covered by these surveys was however limited to the Mafia Channel and around Mafia Island, which is 20km offshore from the eastern extent of the Rufiji Delta (Frontier reports….). There are virtually no catch statistics or other data on the important floodplain lake fisheries (Hopson 1979, Richmond *et al.* 2002).

4.2.5 Forests and associated biodiversity

The coastal forests of Tanzania rank among the world's top biodiversity hotspots. In contrast to the two reserves of Kiwengoma and Namakutwa, intensively studied by Frontier (Clarke and Dickson 1995a, 1995b), the forest remnants of Kichi hills and elsewhere (Nyumburini, Mtita, etc.) have received little or no scientific attention. However, REMP recently commissioned studies on vegetation (Mwasumbi et al, 2000) and two field studies of small vertebrates (Howell et al., 2000; Howell and Msuya, 2001), Galagos (Perkin 2002), dragonflies (Klausnitzer 2001). In addition, an inventory of principle timber resources (Malimbwi, 2000), a survey of the pattern of logging in Rufiji District (Olivier and Graham, 2000) and a strategy for assessing woody vegetation in the Rufiji (Herlocker, 1999) have also been recently commissioned by REMP.

Mangroves

The national archives and the special collection (East Africana Section) in the University of Dar es Salaam library contain material concerning the management of the mangrove forest in early colonial times. However, in general terms, mangroves of Tanzania have not received much scientific attention. There is insufficient information generated to be able to form a picture of the Rufiji Delta ecosystems, their function and the anthropogenic influences on the function (Kamukala and Crafter, 1993). Grant (1938b) recorded mangrove coverage in Tanzania and only in 1989 did an inventory under the Ministry of Tourism and Natural Resources show the recent extent of mangrove coverage in the Rufiji Delta (Semesi, 1991). Mwalyosi (1990), who reviewed the resource potentials of the Rufiji River Basin, did not highlight the potential of mangroves as a valuable resource. However, the Mangrove Management Project under the Catchment Forestry Programme of Forestry and Bee keeping Division has, since the inventory, developed management plans for all mangrove areas in the country including the Rufiji Delta's mangroves (Semesi 1991), in one of the management plans, described in broad but thorough terms the mangrove forest of the Rufiji delta. This management plan includes a section which describes livelihoods in the delta (Von Mitzlaff, 1989).

Studies of coastal communities in mangrove areas have been mentioned under socio-economics and fisheries. The physical programme of Frontier-Tanzania surveyed landforms of the northern margin of the delta, considering sedimentation and mangrove response to sea level rise (Frontier, 1989; Pethick and Spencer, 1990 check the order of the authors). Other studies include the structure of mangroves (Mattia and Malimbwi, 1999), the implications of physical processes on the mangroves (Julius, 1992) and mass mangrove mortality due to El Nino floods (Erftemeijer and Hamerlynck, 2001). The root causes of biodiversity loss in the mangroves of Rufiji (among others) were also reviewed in Wood et al., 2000. Waterbirds of the mangrove forests of the delta have been described by Bregnballe et al. (1990). Another avifaunal survey of the Rufiji floodplain and delta was recently carried out in which terrestrial bird species were also recorded (Nasirwa *et al.*, 2001). A separate desk exercise compiled all bird species recorded in the Rufiji floodplain and delta and will contribute to the Bird Atlas of Tanzania (http://home.no.net/stenill/Tzbirdatlas/tzatlas.htm).

5 The Research Strategy – main scientific questions

Having reviewed the past research efforts, as well as the agricultural and flooding characteristics in the Lower Rufiji, it is clear that the environmental issues facing the Rufiji District management are of a holistic character, exhibiting complex interactions between the geographical (the Rufiji River Basin), the physical (soils, hydrology, climate, nutrients, etc.), trophic (fauna and flora) and human

dimensions (farmers, forest harvesters, hunters, fisherfolk, livestock keepers and tourists) as well as the possible effects of management interventions. This research master plan has therefore been organised following a thematic approach, rather than arranging the scientific questions by geographical, physical, trophic and human dimensions. There are four themes in total but each theme covers a range of issues or sub-themes that should be addressed by research and monitoring. Under these themes, the main questions to be asked are graded into short-, medium- and long-term research and monitoring.

The Short-term phase (1-2 years) involves an assessment of the status, health and emerging issues. Here the general **baseline information** to gain an overview of issues identified should be gathered.

The Medium-term phase (2-5 years) covers the causes of impacts/threats and trends identified in the short-term phase and it includes monitoring of selected indicators/key parameters. This phase involves the understanding of the larger picture including at larger spatial/temporal scales. It is the **diagnosis of causes**, in which issue- or resource-specific surveys and observations will concentrate on cause-effect relationships.

The Long-term phase (5 years onwards). This phase involves the understanding of interrelationships, linkages and trends of a similar scale as the medium-term, but at intensive levels from which data for prediction and modelling can be derived. It is the diagnosis of **interaction and forecasting**, in which intensive monitoring and research is done to determine specific mechanisms of interaction needed to build cause-effect models.

There are two main challenges:

(i) to understand how the Rufiji River affects the functioning of the river-dependent ecosystems (i.e. the relationship between the flooding regime, ecosystem functioning and habitat dynamics) and how all these are impacted by human activities

(ii) to understand levels of sustainable use of Rufiji's natural resources that would alleviate poverty whilst preserving biodiversity.

5.1 Theme 1: Conservation and sustainable utilisation of natural resources

Issues or sub-themes:
- Over-exploitation versus sustainable management of resources
- Use-support systems (ecosystem function)
- Biodiversity
- Degradation of and rehabilitation of ecosystems and water resources

5.1.1 Short-term

<u>Baseline assessment and monitoring</u>

Characterize the problem
Describe the condition of the ecosystems and resources and document in broad temporal and spatial scales the status and trends in resource use
Identify the large-scale existing and emerging issues
Indicators to be measured in the short-term include:
(i) Measures of community and ecosystem structure and function (productivity, abundance and distribution, diversity and important attributes of nutrient and chemical cycling, species composition and diversity in relation to habitat characteristics)

(ii) Environmental stressors and habitat variables. These are measures required to interpret natural variability in dynamic woodland, forest and wetland environments of the Rufiji;

These measures will provide a comprehensive, integrated assessment of the "health" of the area's resources.

Applied research

In addition to improving the ability to document status and trends, research at this level can also establish a means to provide early warnings. Indicators of environmental parameters as well as those that link environment to poverty, a key issue in Rufiji's environmental management, are to be used. This implies that parameters, which serve as appropriate surrogates for system condition and response will have to be defined. To help characterize systems, research is needed to address the following basic questions:

- How can monitoring be incorporated with sustainable use management?

- What should be measured?

Answering this question requires an understanding of the important components of structure and function of the system, an evaluation of the appropriate levels of biological organisation relevant to the monitoring purpose, and the classes of stressors that are potentially important for the resource and scale. For instance, no recognizable "keystone" species have been identified for any coastal forests that might serve as indicator for overall forest ecosystem quality – and an indicator of biodiversity conservation.

- How should such an indicator be measured?

The answer to this question requires a standard protocol to be defined.

- How responsive is the indicator?

It is important to determine the degree to which a particular indicator actually responds to various stressor gradients at multiple scales.

- How variable is the indicator?

Ecological condition reflects the combined effects of natural variability and anthropogenic stress.

5.1.2 Medium-term

Monitoring

Assess the causes of the problems identified in the short-term phase. Collect monitoring data only in areas identified as impacted by the short-term in order to quantify the relationships among ecosystem response variables (productivity, bird abundance, species abundance etc.) and environmental stressors (e.g. habitat loss). This will enable the diagnosis of the cause of an observed environmental problem. It is through this quantification that better stewardship and better correctional operations can be identified. Sampling will be stratified by a given environmental issue, e.g. contamination by heavy metals, invasive species, habitat degradation, fisheries decline, etc. Participatory monitoring, if applied, serves a double purpose, one of which is increasing awareness of the value of natural resources.

Research

This step will determine the causes and consequences of detected changes. Causes and consequences are determined by appropriate process-oriented research with tools to diagnose and predict system dynamics.

Once conditions and trends for an ecological system have been described, it is important to identify which parts of the system are changing, why they are changing, whether particular policies will be effective in dealing with those changes. To answer these questions it is necessary to understand and be able to predict how the system will respond to individual, multiple or cumulative stresses. The link between mangrove ecosystems and the productivity of adjacent coastal ecosystems (ref. coastal fisheries) needs to be directly demonstrated and quantified. Research should address

quantitative and functional aspects of mangrove ecosystems. To couple monitoring results with causes of system change, and to predict system responses, research must address three basic questions:

- How are measures extrapolated across scales of organisation?

Greater understanding is needed about how impacts measured at lower levels of ecological organisation reflect impacts at higher levels. And how altered hydrologic and biogeochemical cycles affect human activity and how people adapt to mitigate those changes.

- What changes in the system structure and function are due to changes in inputs?

Addressing this question requires a sound basis to link an ecological response to change in input. These links can be developed based on observations of co-occurrence of input and response, and an analysis of the strength of that co-occurrence.

- How do human activities propagate through the ecosystem?

Additional research is needed to understand how human-induced changes in the landscape alter hydrologic and bio-geochemical cycles in wetlands and forests woodlands and how the system is adapted to mitigate those changes.

In Rufiji, renewable resources are the sole asset of the region. These are mainly fisheries and forests. The pattern of resource use that enables these resources to regenerate, sustainable management, implies that the management regime employed is important. The continuation and volume of their flow depend crucially on humans. And the challenge of managing these resources involves the maintenance of an efficient sustainable flow.

Economic and political sectors have their role in responding to these challenges, but research should provide a guide to what is the efficient sustainable flow of forests, fisheries and water. Harvesting rules should take into account factors internal to the resource such as rates of resource renewal as well as the external economy (circumstances in which the affected party is benefited by an externality). From the point of view of economics, it is the difficulty of assigning property rights to nature that is the key explanation for too fast a depletion of natural resources and the degradation of the environment. Thus apart from the maximum sustainable yield policy, the economically optimal population size and harvesting level need to be determined by taking into account the stock size, harvesting costs on the stock size and the "*in situ*" value of the animals or plants.

However, in an open access situation (such as is the case with Rufiji fisheries) there are no "automatic" economic forces that can solve the problem of overexploitation. Public intervention is necessary to achieve economic efficiency. Therefore research should provide management with information necessary to guide appropriate/workable regulatory measures. Regulatory measures of the fishery may include,
(i) closed seasons: These are used to limit harvesting during crucial periods when fish population is reproducing. *When is such a period? By how much should harvesting be limited/ what is the maximum sustainable yield?* Even if these goals are met they may still cause economic inefficiency and waste of resources e.g. by excessive working hours for fishermen and large expenditures on capital and fishing equipment to achieve the desired level of harvest. *By how much should the cost of harvesting* (so as to reduce the income level of fishermen*) and the price of fish for the consumer be increased*?
(ii) Gear restrictions: limit the use of "too effective" catching devices or try to preserve the habitat of the harvested population,
(iii) Limited entry, where the authorities restrict the number of fishing vessels (or fishermen)
(iv) Aggregate catch quotas to try and shorten the fishing period. This requires a monitoring system, which determines when fishing should cease because the cumulative harvest level equals aggregate quota.

The authorities should not neglect the economic forces behind overexploitation as this will lead to regulation measures which may temporarily reduce the level of over-harvesting but which still

include the market signals that cause over-exploitation. Nevertheless, renewable stocks should be considered capital assets with biological reproduction mechanism even though economic analysis may provide an interesting perspective on resource utilisation. Without combining economic and biological perspectives, and without correctly designed regulation policy, the economic benefit from these resources, including the value in situ is easily wasted. Due to conflicts that often arise in the face of changing regulations, the participatory research approach should be encouraged, as it is a tool that convinces fishermen of the importance of fishery regulations.

There are three generally known sources of deforestation, which is why forests are being harvested so rapidly, in apparent violation of both efficiency and sustainability criteria. The first source of deforestation involves global inefficiencies. These are external costs that transcend national borders and some international action would normally be necessary: The loss of biodiversity is one of such. Due to species extinction the diversity of many forms of life are diminishing at an alarming rate. Whereas ¼ of all prescription drugs have been derived from substances found in tropical plants, future discoveries are threatened by deforestation's deleterious effect on habitat. Global warming is another external cost caused by global inefficiencies. Deforestation also contributes to global warming. The loss of biodiversity precipitated by deforestation is mostly felt by other countries (industrialised) while stopping deforestation means giving up jobs and income derived from harvesting the wood or harvesting the land made available by clearing the forests. With such global externalities we have a clear rationale of market failure, but also a clear rationale of why governments involved cannot be expected to solve the problem by themselves.

The second source of deforestation is poverty and debt. In Rufiji positive feedback loops have created a downward cycle in which poverty and deforestation reinforce each other. As forests disappear, survival strategies may necessarily sacrifice long-term goals simply to ward off starvation or even death; the forests are typically an early casualty. On the other hand, poverty at national level takes the form of high debts to service in comparison to the capacity to generate foreign exchange earnings. As a result over-exploitation of resource endowment to raise the necessary foreign exchange is encouraged (ref. timber export).

The third source of deforestation is perverse incentives. Profit maximisation does not produce efficient outcomes when the pattern of incentives facing decision-makers is perverse. Sources of inefficiency can be found in the concession agreements, which define the terms under which public forests can be harvested. To loggers, existing forests have a substantial advantage over new forests; they can be harvested immediately. This advantage is reflected in economic rent associated with a standing forest. In principal the government has a variety of policy instruments at its disposal to extract this rent from the concessionaires, but it has typically given out the concessions to harvest timber without capturing anywhere near all of the rent. The result is that the cost of harvesting is artificially reduced and loggers can afford to harvest much more forestland than would be efficient. The failure of government to capture this rent also means that the wealth tied up in these forests has typically gone to a few, now-wealthy individuals and corporations rather than the government to be used for the alleviation of poverty or other worthy social objectives. Because concessions are typically for a short period of time, loggers have no incentive to replant, to exercise care in the logging procedures, or even to conserve younger trees until they reach the efficient harvest age. The future value of forests will not be theirs to capture. The resulting logging practice destroys a multiple of the number of trees represented by the high value species due to destruction of surrounding species by the construction of access roads, the felling and dragging of the trees, and the elimination of protective canopy. Losers from inefficient forest practices are indigenous people whose livelihood depends on these forests.

Research on deforestation should aim to quantify losses due to these inefficiencies and provide decision-makers with concise figures both in economic and ecological terms. This is important so as to signal decision-makers to realise, recognise and correct perverse incentives in order to restore efficiency.

5.1.3 Long-term

Monitoring
Monitoring at short- and medium-term levels provides information that can be used to develop policies and actions to correct problems found throughout the nation. However, problems in the Rufiji, as is the case with many problems, are the result of complex interactions of stressors, habitats, natural hazards, human activities/interventions etc. In order to determine these interactions and forecast the likely environmental response of those interactions, some sites should be selected where measurements carried out are spatially and temporally intensive. Medium and long-term levels of research and monitoring provide an understanding of the seriousness of a particular relationship or issue. This level aids in interpreting results at short- and medium-term levels and links process research with long-term measurements of ecological and environmental measures to strengthen cause-effect linkages and predictive models relating stresses and ecosystem response.

Ecosystem changes take place in the context of ongoing changes in land and resource use. Ecological forecasts of the far-reaching implications of these shifts on ecosystems, and their impact on society, are needed. These include forecasts of changes in the health and productivity of the natural ecosystems that are critical to providing food to the Tanzanian economy – especially forest, agricultural and wetland ecosystems.

Research
Research questions for the long-term are identical to those of the medium-term with the exception that at this level the scale is local, the importance of interactions may be greater, and the role of natural variability may be greater.

5.2 Theme 2: Natural hazards management

Issues or sub-themes:
- Extreme flooding events
- Drought and famine
- Grassland and forest fires
- Invasive species and vermin
- Environmental vulnerability

5.2.1 Short-term

Baseline assessment and monitoring
Measurements in the short-term should be designed to characterize the problem associated with the above issues. In order to identify the large-scale existing and emerging issues, tracking the natural dynamics should be carried out. The characteristics and conditions of forest and wetland ecosystems that are a cause for concern or otherwise warrant attention as well as the factors and processes that regulate these characteristics and conditions should also be addressed at this level. The nature of the hazards and the ecosystems they affect should be described while the status, extent, trends, timing and budgets of various components (e.g. water, nutrients and sediment, etc.) should be documented in coarse temporal and spatial scales.

A useful guide to sound assessment of unwanted species may be obtained from consideration of the normal distribution of the plant/animal in question. A proper and full assessment of the status of the species in terms of rigorous quantitative data of an ecological and socio-economic nature should be obtained in this phase.
Research
To help characterise the floods, drought, fire and invasive species and vermin issues, research is required to answer the following basic questions:

- What should be measured?

Answering this question requires an understanding of the main hydrological parameters responsible for the existence and productivity (and subsequently, degradation) of dry forests and mangroves,

woodlands and wetlands (floodplain lakes) and of the resources they harbour. Hydrology plays a fundamental role in determining the quality and quantity of the natural resources in both the floodplain and the delta. These in turn form the basis for the temporal and spatial pattern of land use activities. Floodplain geo-hydrology and groundwater flows, evaporation within the floodplain and delta and the patterns, as well as the extent, depth and duration of flooding are some of the immediate data required.

Sediment carried by the river especially during periods of intense flooding, but also the amount transported by the river during normal conditions should be quantified and mapped. Specific characteristics for various agro-ecoregions and watersheds should also be mapped at this level. Information should show the general location for steep lands with high erosion potentials, flat lands with low erosion potentials, lands with poor drainage, lands with low crop productivity, lands with various levels of precipitation, lands adjacent to lakes, streams, or ditches, and steep lands next to rivers. Such information should help planners understand the diversity in landscapes, soils, climate, cropping systems, hydrologic features, and water quality impacts.

Research on invasive species and vermin, in addition to being directed towards controlling unwanted species, should also concentrate on understanding the ecological basis of the problem and the effect of the plants/animals on water bodies and agricultural production.

Assessment of the minimal amount of water needed to maintain the complex river, floodplain and estuarine system (especially the mangroves) in the face of demands for transfer of water or upstream damming is difficult. It is impossible to provide accurate measures of how much water is essential for environmental and conservation needs *vis-à-vis* industrial and agricultural needs where development of the catchment is proposed. Components of such systems have evolved to cope with the natural water regime, with its annual cycles and year-to-year variations, and are best left alone.

Two approaches that can be used to determine the minimum water requirements in relation to mean annual run-off are:
- estimating the need for consumptive use (human use, river evaporation, riparian evapotranspiration
- estimating the need for non-consumptive use (maintenance of fish habitat, additional need for sediment flushing, sufficient water depths for maintenance of pools for wild game, flooding of the floodplain and maintenance of its vegetation, appropriate temperature and water quality (especially salinity).

Conversely, floods and droughts are grassroots phenomena and should be seen as an integral part of human life in the Rufiji Region. Because these phenomena disrupt the lives of many people, most of whom rely on subsistence agriculture, scientific effort should move towards studying the wide range of human actions – over which humans have some control- which bring more disasters upon people every year (as opposed to only studying climatological and geological triggers over which humans have very little control). What role are humans playing in natural disasters for us to keep on calling them "natural"?

- How and where should such (climatological, political, social) parameters be measured?

The answer to this question requires a standard protocol to be defined.

5.2.2 Medium-term

Monitoring

In this phase the causes of the problems identified in the short-term phase are diagnosed. Environmental issues related to floods, drought, fire, invasive species and vermin can be stratified (destruction of crops, soil refertilization …). The purpose of monitoring at this level is to quantify the relationships between the hydrological parameters and human-induced changes in the catchment, taking a wide integrated approach. For instance: diverting seasonal river flows in arid and drought-prone environments for development uses such as large irrigation schemes, urban

water supply, industrial use and hydro-electricity. The uses of the wetland resources of the Rufiji for fishing, agriculture, resource harvesting, water supply and other benefits (ref. Turpie) are integrated with that of surrounding dry lands. Thus the floodwaters feeding these areas is not wasted. It is therefore critical that links between the river, the floodplain, physico-chemical parameters and human characteristics are well studied. The relationship between flood extent and lake characteristics should be established.

Following the fact that there is little need for the use of fertiliser in agriculture, nutrient budgets of the river floodplain may be established based on the nature of the flood pulse. This would lead to a greater understanding of the interaction between the hydrologic regime and nutrient dynamics (refertilization/soil fertility) that is behind the ecosystem functioning, floodplain productivity (incl. fisheries) and recession agriculture. What is the interaction between the hydrological characteristics of seasonal flooding and the soil fertility and productivity of the floodplain (i.e. interaction between flood regime and nutrient dynamics)?

Research

Research at this level should determine the causes and consequences of changes. Causes and consequences are determined by integrating relevant process-oriented research with tools to diagnose and predict the dynamics in the system.

Once the condition, trends, status, nature, budgets, patterns, extent, duration, real time and historical hydro-meteorological information have been described, it is important to identify which part of the system is changing and why. Although the analysis of river regime and estimation of flood hazard may well be undertaken by water engineers, many of the adjustments to human activities, particularly the non-structural ones such as flood zoning and flood proofing, require land use planning and building regulation agencies. Therefore an approach in which environmental, ecological, economic, social and political factors are considered is preferred. To couple monitoring results with causes of system change, and to predict the responses, research should address the following basic questions:

- How are measures extrapolated across scales of organisation?

Greater understanding is needed about how impacts measured at lower levels of ecological organisation reflect impacts at higher levels. Assessment of the consequences of upstream river basin developments that divert floodwater away from the floodplain/wetlands on economic benefits is required. An analysis of the impacts of the shift in its course in the 1970s on hydrology of the lower Rufiji (and especially on the floods) is overdue (ref section 4.1.2). Will the river eventually revert to the old channel? What has been the impact of the last El Nino on the accumulated sediments along the old course? What impacts would any changes have on the flash floods? What is the risk of a second channel reversal? The idea is that by comparing similar flows at Stiegler's Gorge with flood data downstream "before" and "after" the shift some predictions may be made on what would happen if the system reverted. Depending on the outcome, some geo-morphological studies of the cork now blocking the old route may be needed. Could there be a link between the change of course at the top of the floodplain and the shift from south to north of the main outflow channels of the delta?

- How do human activities propagate through the ecosystem?

For many human activities, pathways of transmission and adaptation in ecosystems are poorly understood, hindering development of accurate assessment of ecological effects due to human activities. Additional research is needed to understand how human-induced changes in the catchment alter hydrologic and biogeochemical cycles in coastal area, other wetlands, forests and woodlands and if and how the system is adapted to mitigating those changes.

- What changes in the system structure and function are due to changes in inputs?

Addressing this question requires a sound basis to link ecological response to changes in input of water, nutrients, sediments and pollutants. These links can be developed based on observation of co-occurrence of input and response, and an analysis of the strength of that co-occurrence.

The delta for instance is highly dynamic and is characterized by the deposition of sediments primarily derived from the river catchment. The dynamic alteration between sedimentation and erosion is quite subtle and easily lost when natural or anthropogenic changes in flow characteristics are brought about within the river basin (or the delta itself). Because of such dynamism, scientific questions should first address what the minimum requirements are of the processes, which maintain the functions and productivity of the natural wetlands. How much water is needed, over what time spans, in which seasons and of what quality in terms of e.g. minerals, nutrients and sediment loads to maintain vital ecosystem functions? What is the economic value of the services provided by the natural ecosystems and what are the replacement costs if these were lost?

Changes in river flow can either be an increase in sediment inputs due to natural or human induced changes in the catchment, e.g. deforestation or a decrease in sediment input, as is the case after construction of dams. The effect of human action on geo-morphological activities and sediment quality should be established at this stage too. Saville (1945), reporting on flood regimes of the Rufiji in the 30s and 40s, suggested that an increased rate of run-off (as a result of the destruction of the natural vegetative cover in some portions of the Rufiji basin), rather than a cycle of years of high rainfall, was the underlying cause of the increased amount of flooding that occurred in the Rufiji in the 10 years before 1945.

5.2.3 Long-term

This involves the diagnosis of interactions and forecasting deriving from the fact that many problems related to flooding and/or drought are the result of complex interactions of the natural environment and human activity. The wetland ecosystems of the Rufiji are potentially subject to multiple causes of ecological change. For example an intervention such as dam construction may alter the hydrologic regime of the floodplain, while altered climate (new precipitation and temperature patterns), the extent to which land and related resources are used may enhance drought. Building the ability to forecast the cumulative/interactive effects of these multiple stresses is the most significant challenge in ecology.

This level may provide an understanding of the seriousness of a particular relationship or issue and aid in the interpretation of results from short- and medium-term studies. Short- and medium-term process research, linked with long-term measurements, will strengthen cause-effect linkages and predictive models, show the effects of future disturbances and allow for the making of predictive statements on the net effects of alternative floodplain modification strategies on the geographical, physical, trophic and human dimensions.

While extreme natural events (floods, drought, fire) are largely outside the control of natural resource managers, the ability to predict their occurrence and ecosystem effects, as well as their interactions with other causes of change, are important for planning management and response activities to minimise damage and enhance ecosystem resilience. Similarly, ecological forecasts of the introduction, spread, and ecological effects of introduced species are needed in the long-term.

5.3 Theme 3: Socio-economic development

Issues or sub-themes:
- Poverty and economic insecurity
- Linkages between poverty, environment and education
- Communication gaps
- Economic versus environmental vulnerability
- Impacts of large-scale development and environmental interventions

5.3.1 Rationale

Development is defined as the qualitative increase in the non-physical: structure, design and flows that result from greater knowledge both of technique and of purpose. Thus, it does not necessarily

lean on the linear economic growth model, but also looks at the dynamics of the natural system to value and characterize externalities.

Poverty and environmental linkages in Tanzania
What are the linkages between poverty and the environment in the Rufiji? A number of critical linkages are laid out between poverty reduction and environment. These are:

(i) Economic opportunity/livelihoods and the environment
Firstly, there is a direct link where environmental degradation reduces the opportunities for livelihoods based on natural resource products such as food, fodder, fuel and medicines. The access the poor may have to natural resources may also depend on property rights (formal or informal). But these opportunities are heavily affected by tax, subsidy and pricing system as it affects the poor especially landless labourers. Poorer people have greater dependence on natural resources and therefore have access to fewer alternatives.

(ii) Capability or health and the environment
Environmental conditions play an important role in determining people's health (e.g. sanitation, water quality and quantity). There are a number of environmental factors that have a direct link with health and thus with poverty, broadly defined. Diseases that are related to the poor quality of available (drinking) water sources and/or dirty air reduce the capability of the poor to do work because of damaged health. Poorer people are more susceptible to health risks due to their lower ability to respond.

(iii) Security and the environment
Natural disasters and climatic variations reduce security. Poorer people are more vulnerable to shocks inflicted by natural environment because they depend highly on natural resources for livelihoods than other income generating activities. They often live in environmentally vulnerable areas that are already degraded. They also lack social safety nets to protect income and consumption during crisis (assets, access to credit).

5.3.2 Short-term

Baseline assessment and monitoring
Short-term studies should aim to characterise the problems associated with economic development in the lower Rufiji and describe the nature of the problems. Environmental services provided by the wetland ecosystems that support present economic activities should be defined. National economic strategies that affect livelihoods may also be identified. Information on livelihood security strategies may be mapped as trade routes and marketing chains are described. The conditions for and trends in socio-economic development should also be described at this stage. In censuses and surveys lie the opportunities for addressing poverty-environment linkages. Analysis of existing data sets such as those of the Household Budget Surveys should shade some light on changes in incidence of poverty and for evidence of the dependence of the rural poor on natural resource products as sources of income and consumption.

Research

To help characterise the problems that have been identified research is needed to address the following basic questions:

- What should be measured?

Answering this question requires understanding of the important socio-economic profiles, including linkages between poverty, environment and education. Factors that underpin economic development under the conditions described should be established. Identification of appropriate indicators at district level to reflect progress in activities undertaken within the framework of Poverty Reduction Strategy Paper (PRSP) is crucial. Studies could be commissioned to look at existing indicators especially on specific activities aimed at poverty alleviation. An assessment of the various community-based environmental management projects and programmes can be

undertaken to identify good practice and examine the evidence they provide of the impact of environmental activities on the livelihoods of the rural poor. This will also provide input into the process of identifying appropriate poverty-environmental indicators.

- How should the indicators be measured?

The approach taken should not lamp all indicators, but choose a few and after interventions, try to quantify the effects on that indicator. Areas of overlap should be identified (between high poverty and high degradation) and then undergo monitoring in those areas, while retaining national level indicators. Monitoring can only occur when indicators are identified at various levels (district as well as national).

- How responsive should the indicators be?

- How variable are the indicators?

5.3.3 Medium-term

Research

Make a diagnosis of economic incentives and disincentives that control natural resources as well as non-economic incentives such as cultural/spiritual influence. Research at this level should determine the causes and consequences of changes detected in household budget surveys and identify alternative income generating activities. Identify where changes are taking place and why, taking into account any influence of social change, shifts of national policies and economic strategies. Research at this stage should improve the understanding of the impact of various activities on poverty so as to address fundamental issues of dependence of the poor on natural resources. Research that improves the understanding of the impact of activities on poverty should be carried out. Some of the fundamental issues about the dependence of the poorest on natural resource assets, the extent to which this is gender specific and the potential of environmental or natural resource interventions for reducing poverty should be addressed and supported with quantitative arguments under each theme.

5.3.4 Long-term

Quantification of economic benefits of various interventions may take place at this level. Diagnosis of interactions and forecasting of the likely response to those interactions are the components of long-term monitoring. Impacts of economic development projects should be established.

Economic and hydrological studies should reveal the costs of diverting water from the natural floodplain(s) and improve the understanding of the impacts of water diversion on the floodplain and the delta. This adds further to the need of a hydrological modelling of the river basin and the floodplain and should include analyses of impacts of upstream development through flooding scenarios, and evidence of socio-economic importance of activities undertaken presently by local communities living in and nearby the floodplain. Studies should clearly indicate how the floodplain functions to recharge shallow underground aquifers and estimate the economic effects of changes in flooding from upstream water development on ground water recharge function. The output of hydrological-economic studies should be the likely economic impacts on floodplain agriculture, availability of fuelwood, charcoal, poles and timber, fishing yields and wildlife benefits of different flooding regimes.

Tanzania's poverty reduction strategy (PRS) (which focuses on poverty eradication, and the development of a strategy aimed at reducing income poverty, improving human capabilities, survival and social well-being and containing vulnerability among the poor) should benefit from seeing the clear link between poverty and the environment. In relation to the economy and the society, the environment should ideally overlap with the two, and not function separately nor in the wrong perspective where economy is the centre of focus while environment lies in the outermost circle, and often regarded as a deterrent to economic growth. Furthermore, the National

Environment Action Plan (NEAP) identifies six major problems for urgent national attention. These are land degradation, lack of accessible good quality water, environmental pollution, loss of wildlife habitat and biodiversity, deterioration of aquatic systems and deforestation. Although these important areas require attention in their own right, the case has to be made either that environmental activities are effective ways of addressing the main areas of focus of the PRS, or that lack of attention for environmental issues will reduce the chances of success of critical elements of the poverty reduction strategy. Detailed analysis of poverty-environment linkages is therefore imperative and should be quantitative.

Environment touches on activities of many of the line ministries such as agriculture, livestock, mining and transport. It is expected that environmental concerns will also be addressed in the context of the Agricultural Sector Development Strategy (ASDS) and the Rural Development Strategy (currently being developed). ASDS is oriented towards developing a commercial agriculture sector, however, as the PRSP recognises, many of the poorest in Tanzania are dependent on access to natural resource assets for their livelihood, and the return they receive from those assets. Therefore there is a potential case for including within the PRS environmental activities aimed at improving these livelihoods based on better access to and management of the resources. This is the point where long-term research in Rufiji must come in to provide information on which to base this argument.

Understanding the livelihood strategies and cultural constraints and their relation to the current educational systems and levels is required. Ways in which the educational systems need to be to appeal to livelihood needs should be identified.

5.4 Theme 4: Policy and Decision-making

Issues or sub-themes:
- Institutional capacity and role of institutions
- Decision-making process
- Interlinkages between natural resources management policies and other policies
- Mechanism for co-ordination and benefit sharing

5.4.1 Rationale:

There are many relevant policies (usually sectoral) pertaining to environment and natural resources. The legislation, however, required to aid in the effective implementation of the statements of intention in the policies, are often out-dated. The scope of national policies is narrow and does not take into consideration environment in its entirety. The Rufiji floodplain & delta region provides an ideal opportunity to examine (as a case study) the constraints to effective implementation of national policies and legislation with regards to environmental management and sustainable development.

This research is an integral part of the integrated monitoring and research strategy to provide useful information on which management decisions now and in the future can be based. It may also lead to national programmes to focus on urgent issues while building partnerships among managers at local, regional and national levels including stakeholders to achieve the goal of wise development.

This research will also help to determine if national policies related to the environment are having desired effect and through what other means can environmental management goals be achieved. While monitoring can point out whether management actions are achieving the desired goals, research is required to reduce the uncertainties in environmental cause-effect relationships. Because management actions involve change in behaviour, it is important that economic and social considerations inherent in decision-making process are assessed. Research should address the following questions:

- How are different management options evaluated to select the best?

Which options are in place? Methods should be developed to model ecosystem responses to changes to allow simulations of potential future scenarios under different management alternatives.

- How are ecological services and functions valued in the decision-making process?

This requires the ability to predict economic consequences of environmental change. Methods to assess and predict non-monetary benefits and impacts on livelihoods are needed

- How is human response to management actions measured?

Achieving desired results from many management decisions hinges on the willingness and efficacy of people to change their behaviour. Indicators are needed to measure this change in behaviour

- What is the impact of national policies on the observed trends in resource use?

The answer to this question hinges on the effectiveness of implementation of given policies as well as legal backing of such policies

6 The scientific programme

6.1 Introduction

This chapter aims to provide a strategic framework to make informed decisions regarding research projects anyone wishes to carry out or support in the Lower Rufiji. During a recent workshop, scientists have worked with managers to prepare concise statements of objective for research and monitoring in the Rufiji area, facilities and personnel needed for the studies to be successful and cost-effective. However, further collaboration between scientists and managers is needed in order to define what is to be measured and why and identify suitable methodologies. Nevertheless, under each priority issue to be addressed, scientists and managers have attempted to formulate specific questions that are to be resolved through subsequent scientific investigations (using the principles outlined earlier in this document (chapter 3)). Information carried in this plan can be used to coordinate priority research tasks and to assess proposals for support. It will also be beneficial for scientists who wish to assist in providing a scientific basis for management of Rufiji's resources and their utilization. This plan will assist them in developing research proposals that specifically address the management needs of the Lower Rufiji Valley. This information will also be useful for funding agencies by highlighting the key research areas of interest for Rufiji's resources and people.

6.1.1 Setting the research programme

The identification of research needs for an area of such complexity endowed with rich resources but at the same time faced with the threat of overexploitation and poverty is not an easy task. To assist in the process, researchers and managers of various institutions in the country were visited and confronted with the issues Lower Rufiji is faced with. Their views regarding research needs in the Lower Rufiji were sought as commissioned by the Rufiji Environment Management Project. With a concerted effort to facilitate the process of developing a research master plan for the area, information was gathered on research interests and capacities of research institutions, while management and decision making institutes were visited for their input into what they considered priority issues that research could answer. A general discussion paper on research needs in Rufiji was then written incorporating the views of both the scientific community and the Rufiji district managers.

In addition, a series of local stakeholder meetings brought out what they considered the critical issues in the area. These earlier workshops identified relevant stakeholders at local, district, regional and national levels. Pertinent natural resources management issues were outlined by the stakeholders, first on sectoral basis e.g. forestry, fisheries, agricultural, and later clustered into thematic areas.

The outcome of the stakeholders' meetings together with the research needs outlined in the discussion paper formed the background for a workshop that was held as the next step in the development of the research master plan. In this workshop, "Towards a Research Master Plan for the Rufiji Floodplain and Delta", attended by both scientists and managers, the important knowledge gaps in each thematic area were identified and prioritised.

During this participatory workshop, an effort was made to refine short-, medium- and long-term research priorities making use of what the stakeholders had identified (in two earlier workshops) as the critical issues. It was also the intention of this workshop to identify interdisciplinary teams. The scientific programme outlines research tasks that would address those needs.

Available records, typically from unrelated sources, have enabled a broad and general review of scientific information from past studies on the Lower Rufiji Valley. These findings however, cannot be conclusive as more details, particularly from older studies, which could not be obtained, probably exist but would require a more extensive search of Journals such as Tanganyika Notes and Records and other collections beyond the scope of this exercise.

6.2 Main research findings summarised

6.2.1 Conservation and sustainable utilisation of natural resources

Biodiversity

Over 140 tree and shrub species were recorded in 2.75 ha in Kichi Hills, a coastal forest within the Rufiji area, which ranks among the world's biodiversity hot spots. The forest is in mid-successional state, recovering from past clearing or logging events. The forest has rare species of flora, but also those species threatened by over-harvesting such as *Milicia exelsa*, *Dalbergia melanoxylon*, *Newtonia buchananii* and *Markhamia* spp (Mwasumbi et al., 2000).

Kichi Hills' fauna include forest-dependent populations of threatened elephant shrews and forest-dependent reptiles. In contrast to the forests north of the river the south of the river has shrew populations which are highly polymorphic and there may be hibridisation of *Rhynchocyon petersi* with *R. Cernei*. Two toads endemic to the Eastern African coastal forests, *Mertensophryne micranotus* and *Stephopaedes loveridgei* have also been recorded in these forests (Howell et al., 2000). However, besides records of species, little of their biology is known. Kichi Hills has sufficiently high densities of both toad species to allow further study (Howell and Msuya, 2001). Kichi Hill's intact forest cover has important bird fauna although data is scanty (Howell et al., 2000).

In the mangrove forests, poverty and isolation drive degradation of the local natural resources. Persistent conflicting government policies and lack of effective environmental law enforcement, together with centralization of decision-making on resource management aggravate the impacts of poverty. The root cause of biodiversity loss in the Rufiji mangroves is driven by strong local dependence on natural resources, particularly for cash needs. Among others, expansion of rice farming, increasing world demand for prawns and the liberalization of the fishing sector in connection with international influences on macroeconomic policy reforms are some of the causes of biodiversity loss (Wood et al., 2000)

Overexploitation of resources

Because the best agricultural lands are in the floodplain and therefore often far from the villages that were created in the 70s during the villagization campaigns (*Ujamaa*), forests (and miombo woodlands) have become the prime provider of income, both for the communities and the government. Timber species in Rufiji's coastal forests constitute an average of about 29 % of the total volume of all tree and shrub species with the number of tree timber species varying between 8 and 17 per forest. Some hardwood species, *Melicia excelsa* (Mvule) and *Pterocarpus angolensis* (Mninga) have become very rare due to overexploitation. Loggers are now targeting other species such as *Afzelia quanzensis* (Mkongo), *Dalbergia melanoxylon* (Mpingo), *Swartzia madagascariensis* (Mgoso), *Milletia stuhlmanii* and *Brachystegia speciformis*. Many of these are deformed and diseased and are considered commercially unattractive. One survey observed only three of these species in millable sizes in only three of the forests indicating that harvesting has clearly exceeded natural regeneration in these woodlands and forests. The current potential of miombo-dominated forests of Rufiji to supply timber is low due to over-exploitation. There is pressure on a few commonly known tree species used for timber. Illegal harvesting of timber and poles is rampant in Kichi, Utete, Weme, Mtanza and Mbunju forests. The present day logging rates cannot be sustained and are causing advanced degradation. Preliminary results from both biodiversity studies and forest inventories suggest that some forests have been virtually denuded of timber trees and that regeneration is poor. The use of lesser-known timber species has been recommended (Malimbwi, 2000) in order to alleviate pressure on the few commercially most attractive tree timber species. However, it is likely that these forest fragments will be further denuded.

A survey of the woodlands and closed forests of Rufiji (except mangrove forests) showed that the entire wooded area of the district was or had recently been selectively logged. In the woodlands and forests the overall average density of stumps of more than a year old was 22/km^2 and the

average density of stumps cut less than a year ago was 3.2/km^2. The intensity of logging was also observed to be higher in the south of the river (15 stumps/km^2 surveyed) than in the north (9.3 stumps/km^2 surveyed).

Land use and vegetation cover in the Rufiji Delta

A comparison of land use and vegetation cover in the Rufiji Delta was made for the years 1967/68 and 1988/89 using photogrammetric survey and satellite images. The scale of change in cover type within the delta was quantified. The redevelopment of mangrove forest from disturbed mangroves scrub was in the range of 3.5 to 68.4 km^2, showing a healthy regeneration rate. An increase in the area of cultivated land in the delta (for rice production) was shown to be between 20.8% and 225.2% correlating closely with estimated area based on local information (1000 farms of about 2 ha each, 20 km^2). It has recently been estimated that, in the northern delta alone, over 2000 ha of mangrove have been cleared for rice cultivation (Hamerlynck pers. com.), while some additional areas had been cleared for settlements. The settlement on Kiomboni island (then with a population of 1500, the most densely population island settlement) had grown substantially. Other settlements in the higher reaches of the old river course have disappeared and the emphasis is now on rice agriculture in the northern Batja region.

Regeneration of mangroves is witnessed south of Batja, just above the old river course, although a substantial reduction in forest borders is shown to the east of this point. This was thought to be a combination of the effect of commercial pressure on the more fragile forest margins and a diminishing supply of nutrients and freshwater, associated with the change in river course (ref?).

6.2.2 Natural hazards management

Floodplain soils

Bearing at the back of the mind that a possible land use problem would emerge from the construction of a power station at Stiegler's Gorge, and the people would have to be moved to the terraces, an integrated resource survey approach was used to obtain information on soils of the floodplain (Cook, 1979). Two land systems, the floodplain and the river terrace, were distinguished on the mosaics and five floodplain land units (former river channel; levee; depression; levee over former river channel; depression over former river channel). All except one of the floodplain land units had soils with a fair degree of heterogeneity (texture).

Mottling occurred throughout the soils of the levee land unit while some moisture retention was evident in the dry season in contrast with the former river channel soils. The soils of the depression land unit, also characterized by narrow textural horizons (usually of clay loam and clay texture with occasional loamy sands) had a generally strong and blocky structure. Ferric oxide mottling occurred at all depths and the subsoil was moist although the topsoil was dried out and exhibited vertical cracking.

Land use potentials generalized from these physical soil and site characteristics showed that the only limitation of the floodplain land units is the flooding itself, with waterlogging presenting a problem in the depressions and lower water holding capacity posing a constraint in the former river channels. These characteristics are reflected in the wide range of crops which can be grown on the levee and the more restricted range in the depression, whilst cultivation is uneconomic in the former channels.

Overall, the picture of land use potential which emerges in this area is of a flood plain with minimal physical and chemical limitations, capable of supporting a wide range of cash and food crops (Cook, 1979). Considering the question of likely flood elimination and mechanized irrigation this obviously would lead to a decline of nutrient levels in the floodplain, although information is scant as to the expected rates of decline. However, land units showed variability especially of soil texture, and this poses a potential problem in the evaluation for an irrigation scheme since water supplied should be carefully adjusted to soil texture.

Flooding and agriculture

From the point of view of the dwellers of the Rufiji valley the duration of the floods is as important as the height at which they rise, and agriculture depends on moderate annual floods as a rule. The danger point is reached when the water level exceeds the 10-foot mark on the gauge. Under the flooding regime that existed before 1935 such abnormal floods occurred on an average of 12-15 years, but this has changed to much more frequent high floods as a result of an increase in the rate of surface run-off (Seville, 1945).

The deposition of nutrient rich silts in the floodplain adds to the productivity of floodplain agriculture (though this phenomenon has not been quantitatively studied). Yields are significantly higher in floodplain areas than in corresponding dryland area, while the production of such crops as rice, which cannot be grown in upland areas, is ascribed wholly to the flooding function. Using the financial value per ha of dryland crops that can be grown on seasonally flooded areas such as maize and vegetables, the financial value of flood inputs to agriculture has been estimated to be roughly $ 2.75 million per year (Turpie, 2000).

Delta hydrodynamics

The major river drainage shift in the 1970s has resulted in an enhanced freshwater outflow within the densely vegetated northern delta and the subsequent expansion of subsistence rice agriculture within the mangrove forest. A review about the hydrology of the Rufiji river basin concluded that sediment transport through the Rufiji River was significant, the river having the capacity to transport up to 500,000 tons of sediment daily during flood discharges (Temple and Sundborg, 1972).

An environmental impact assessment presented detailed topographic and morphological data from the Rufiji River below Stiegler's Gorge (Tesaker, 1979). Hypotheses were presented on the changes in hydraulic regime with the construction of the Stieglers Gorge dam. The work showed that the new dam would initially not alter sediment transport in the lower Rufiji river, as virtually sediment free discharge water from the dam would erode the downstream river bed until an equilibrium was reached, and the great depths of alluvial deposits at this location would ensure that the sediment source would not be exhausted before reaching an equilibrium. The report predicted that the degradation of the seaward margin of the delta would be less than 1 m per year even after the river bed slope stabilised and the source of downstream sediments diminished.

It has been demonstrated that a substantial part (~ 50%) of the suspended sediment load of the Rufiji river is advected through the river mouths and deposited in the nearshore area by wave action. Overall the delta appears presently to be neither prograding or eroding substantially, with the exception of local changes resulting from a re-distribution rather than a variation of sediment fluxes. The input of sediments into the delta is therefore approximately matched by accretion, subsidence and longshore drift. If 90-95% of the sediment source is removed via the construction of a new dam at Stiegler's Gorge (Tesaker, 1979), it is difficult to see how this will not have a significant impact on the delta shoreline.

Francis (1992) examined mixing between nearshore and estuarine/offshore waters in the Rufiji delta and demonstrated the existence of significant trapping of nutrients in the nearshore zone, enhancing the productivity and regenerative properties of the mangrove swamps. This trapping phenomenon is thought to be a result of the prevailing wind (always onshore) and current conditions (Iversen, 1984).

Tafe (1990) correlated biodiversity of zooplankton with salinity levels in the Rufiji Delta. A much richer and more diverse fauna existed at the river mouth and estuary compared to the upper reaches. He predicted that following completion of a dam at Stiegler's Gorge, nutrients would be transferred from nearshore to inland fisheries.

Measurements of longitudinal salt profiles in delta rivers (channels?) in 1978 and again in 1993 showed a northern migration of fresh water from its previous eastern outlets, supporting a

hypothesis of substantial northwards freshwater drainage shift in the Rufiji River delta (Fisher, 1994). The drainage shift was a consequence of the river course (above the delta plain) changing substantially. The change was in such a way that in 1988/89, a whole section had been truncated and had been replaced by a more northerly route at the point where in 1967/68 it approached the main branching point for the northeast section. The same study discussed the dispersive mechanisms on the advective flow. It demonstrated that such mechanisms are generally significant and are capable of replacing 10 % of the net advection during higher discharge periods, and, combined with upstream advection on the Strokes drift, put the estuary into a near steady state during periods of low discharge.

Approximately 70 % of the annual sediment discharge by the Rufiji River is washed down during the four wettest months February to May. Upstream transport of sediment in the delta occurs during spring tides as a result of enhanced lateral and vertical shear associated with stronger tidal currents. A corresponding net seaward transport of sediment is observed during neap tides. Significant accretion of sediments occurs on the islands of Simba Uranga and Kiomboni (northeast section of the delta), as shown by both discharge (derived from a correlation established using discharge transport/relationship) as well as observed accretion on both islands. Accretion at Kiomboni was higher (37 mm/year) than at Simba Uranga (9 mm/year) (Fisher, 1994). Hence it appears that riverine and marine sediment inputs are equally important and the degree of dominance varies with season.

Examination of Remote Sensing Imagery revealed no substantial erosion or progradation of the delta margins between 1968 and 1988, although evidence of an increased sedimentation in the northern delta was witnessed. This was characterised by the choking of minor channels and the longitudinal extension of braided channel deposits (ref?).

A preliminary flood warning model has been produced which forecasts at a one day lead time in Utete, Mloka and Stiegler's Gorge (WREP, 2000).

6.2.3 Socio-economic development

Sorensen (1998) studied the relationship between spatial dynamics of wetland resource quality and quantity and the local people's arrangements for coping with and optimizing on these dynamics. Her research sought to show that by considering the implications that spatial dynamics have on resource management strategies, some of the strategies, especially those related to resource access controls, may become easier to deduce or describe.

Concerning livelihoods in the Rufiji, Sorensen (1998) argued that the people have established a culture that reflects the reciprocal relationship developed between people and their environment. Because most people take part in all the main strands of the economy (fishing, farming, pole cutting) the implication is that there are few that specialize in one activity alone.

The characteristic features of the culture and economy of the Rufiji Delta are fourfold: the wide range of livelihood options available, the mobility in the livelihood systems, the general lack of specialization and the knowledge of how to make use of the highly dynamic ecosystem.

Due to fluctuations in conditions throughout the delta ecosystem, the quantity and quality of natural resources in a location can change over time. Local people, who can benefit from knowing how to access the influx of valuable resources, optimize on this. However, added to the predictable fluctuations, extreme or occasional ecosystem events may radically affect the natural resources in a location in an unpredictable way. Although the outcome of occasional change is quickly recognised, the effect of change may be different each time it occurs. It is argued that in an environment like this, direct or fixed resource tenure arrangements are unusable and even establishing a strategy for livelihood can be difficult. This means that the challenge in the Rufiji is to find out how changes in the environment are met with arrangements which do not hinder equity in the access or threaten the affected segments of society with impoverishment, yet supply some

sort of security to people who are lucky enough not to be affected by change at a given time. The argument describes the unique adaptation by the people to their environment. However, despite such an argument, it is worth noting that, in the past, this area has been among the most fertile and productive areas in Tanzania, thanks to the dynamics of the river. It follows therefore that other factors, other than the river dynamics *per se,* must have contributed to the current unproductivity.

Local terminology was seen to be an important tool in socio-economic research. Without comprehension of these terms, understanding explanations of technical issues can be difficult, as these terms are used in the explanations. For instance when trying to record fishing technologies and practice, without access to the local categories of phenomena such as wind and tide, it would be difficult to understand the description provided. Clearly visualization methods are useful for expressing this knowledge.

When relating history of the resource use to the history of environmental change, related again to institutional controls, it was found that although local people have quickly and effectively adapted their practices to the changed conditions for exploitation, institutional controls have not changed significantly, despite the powerful influences on the Rufiji Delta economy of foreign institutions over the past two hundred years. The local institutional controls over resource management that seem to contain the flexibility required for a mutable environment are (I) knowledge and tenure (knowledge as a regulating institution) and (ii) social organisation and resource tenure.

Another socio-economic study (of the Delta people) surveyed 54 households in four villages in the Rufiji Delta in order to contribute information on economic activities, use of surplus, coping strategies, dependence on natural resources and energy use (Hogan et al., 2000). This, and other similar studies (Von Mitzlaff, 1989; Sorensen, 1998; Kaale et al.; Turpie, 2000; Mbiha and Senkondo, 2001) have acknowledged the high reliance on natural resources as well as remarkable poverty levels in the lower Rufiji. The study recommended that any interventions to improve people's livelihoods would be to concentrate on promoting environmentally safe agriculture while improving environmental management through intensive practical education of the people (Hogan et al., 2000). The study showed that those households that have gained a Standard seven (primary) education earned more than those who have not, which imply the need for educational level improvement. In another study (Mbiha and Senkondo, 2001), seasonal migrations were found to have adverse effects on school attendance by children. While the majority of respondents were in the productive age below 60 with an average of 6 years of education, 42% did not attend formal education. There is varied perception in the state of the environment by villagers. An appreciation of sustainability issues has not been engendered in these communities because until only recently they have had access to abundant resources, and some of the impacts of overutilisation are not likely to be felt by the users themselves. Overexploitation is fuelled by demands from outside the study area, as well as inappropriate or ineffective institutions and systems in control.

A resource economics study covering the river, floodplain and delta, noted that the area's rich wildlife and plant resources formed an important part of the livelihood of approximately 100 000 inhabitants in addition to their agricultural activities (Turpie, 2000). The study, which served to articulate the value of natural resources to the local population, also investigated some of the economic and other factors that determine household behaviour and threaten the future value of natural resources. According to this study numerous natural resources are harvested locally and processed in the area with a high proportion of households involved in many of the activities. Turpie (2000) gives a summary of the total estimated value of the different natural resource harvesting and value adding activities. Turpie (2000) estimated that natural resources in the study area have an economic direct use value of USD 10.3 million per year. The total net financial value (net value to households in terms of home consumption and cash income) of natural resource use was estimated to be USD 575 per household per year, of which a large portion is realised as income. Over 70 % of this value is attributed to the area's fisheries. However, the above values are only part of the total direct economic value of natural habitats. Indirect use value such as flood attenuation, ground water recharge, sediment retention, inputs to agriculture, water purification, nursery functions, micro-climate regulation and carbon sequestration should also be included.

Nearly all households in the floodplain and delta have fields and consider farming as their primary economic activity. At least 24 types of crops are grown, with rice, the staple food, being grown by 76 % of households. Such crops include maize, millet, sweet potatoes, cassava, coconut, sesame, vegetables and fruits. Cash crops make up less than 10 % of the estimated net market value of USD 2.6 million per year, while rice make up over half of the value (Turpie, 2000).

Including rough estimates of income from other businesses as well as from agriculture and other natural resources, Turpie (2000) estimated that natural resources account for 33-59 % of net income to households (including subsistence income), and 32-63 % of household cash income. This implies that natural resources are extremely important in the household economy of the study area. The gross financial value of natural resources in the area is more than double that of agriculture. Furthermore, natural resources are particularly important in providing livelihood security to poor households and in years of poor agricultural production.

A comparison of net financial returns to labour time for different agricultural and natural resource use activities can explain household strategies to some extent. Returns are highest for timber cutting and prawn fishing, which coupled with the high demand for these products, explains the abundant and increasing supply of labour for these activities. This has resulted in unsustainable exploitation (harvesting of hardwood species is currently estimated at 12000 trees per year, including protected species, undersized young trees and trees in forest reserves; the harvesting itself is done in a very wasteful manner). Returns are also high for canoe production and medicinal plant collection, but these activities have low demand. Crop cultivation yields low returns, yet takes up a major proportion of household labour time (woodland is converted for dry land agriculture and cash crops, sometimes on slopes adjacent to water bodies). Fuel-wood collection is another low-value, but time consuming activity, which is carried out by women out of pure necessity. This, according to Turpie (2000), is the only low-value activity that may be having a significant impact on the environment, simply due to the scale of the activity.

Securing and improving the future livelihoods of people within the study area requires optimal mix of development and conservation action, as well as careful decision making beyond the study area. Demand for charcoal and timber in urban areas through exploring alternatives require to be addressed by the government. The study suggested that national level decisions also include those which affect broad scale habitat alteration (e.g. commercial prawn farming initiatives or oil exploration) or the hydrology of the area (Stiegler's Gorge Dam). Local level decisions include those that involve (small-scale) development schemes for agriculture or industry.

6.2.4 Policy, institutional structures and legislation

Assessment or research work that has been done on policy and legislation has not been restricted to the Rufiji only, but covers national policies. An inventory of policies in the environment (Local perspective, 1997) obtained an overview of Government of Tanzania policies concerning the environment at the time when a wider study to define a management and legislative framework for the environment was underway. The study found that in addition to the approved National Environmental Policy, there are over fifteen other policies directly concerned with aspects of the environment. Whilst the study did not attempt to analyse the policies, it was clear that most of the policies have a narrow focus and do not consider the totality of the environment. The need to publicise and disseminate these policies was identified by the poor awareness of the policies among government, donors, NGOs and the general public. The policies are summarised and associated legislation and other key documents are identified. However, as these policies come ahead of any strengthened institutional framework, there are concerns that they only consider sectoral objectives and do not take a holistic approach to the environment.

An institutional and policy matrix, prepared as an input to the Tanzania Green Paper was produced (Makaramba and Kweka, 1999). The matrix, prepared with regard to proposals and options for the institutional framework for implementation of Integrated Coastal Management (ICM) policy,

indicates how issues identified by TCMP for inclusion in national ICM policy are addressed in existing policies, legislation and plans. The matrix describes the status of each policy, legislation and plan, its implementation strategy, and the gaps and conflicts among them. Laws that are related to ICM and their enforcement records were also summarised. The links among various agencies responsible for coastal management, their place in existing government structure and the responsibilities of the various line ministries and local government authorities with a stake in ICM, was summarised. Among others the matrix concluded that:

(i) the multiple policies, plans, laws and mosaic uncoordinated sectorally based central government agencies that are related to one or more of the components of coastal zone management are a recipe for conflict.
(ii) There are a number of gaps in policies plans and legislation, as well as conflicts among sectoral central government agencies and local government that affect resource conservation and utilisation, and decision-making in coastal management.
(iii) Frequent changes in the responsibilities and structures of various sector ministries have not been followed by revision in the respective legal framework, while the roles of line ministries and local government authorities in coastal management is unclear.
(iv) Links and co-ordination between the central and decentralised levels are weak.
(v) Research and training institutions lack strategies for conservation (+coastal management) research and training, contributing to a lack of human and institutional capacity for resource policy implementation and management.

6.2.5 Conclusion

It appears that there has been a wealth of useful information gathered in the Rufiji basin in general. However, what might have seemed to be wanting is how to involve communities in identifying research priorities and information collection, especially when it comes to environmental information. The need for advocating for participatory action research cannot be overemphasised. Although the number of documents on Rufiji may have appeared impressive, the technical information and data on the Rufiji remains limited in scale and scope and (in some cases) poor in quality/reliability. Syntheses and review studies are largely lacking. As is the case for many areas, research in the Rufiji appears to have been outsider-driven, incidental, single-disciplinary, and usually not guided by information needs identified by resource managers or users. Most of the data available are incomplete in terms of temporal and spatial coverage. Most baseline studies are incomplete, and not quantitative. Most science gaps identified point to the lack of monitoring data, lack of experimental studies and narrow geographic coverage. In addition, the breadth of subject coverage in past scientific investigations has also been narrow. These include the lack of studies on: linkages between pollutants and physical force; biological studies and minor fisheries; communication and dissemination of scientific findings; links between local researchers and their institutions; inter-linkage between ecosystems; standardising data collection methods and improved fisheries data collection and fisheries statistics. Finally past research efforts have had little or no planning, no integration or co-ordination with a view to meeting information needs for better management of resources.

6.3 Research challenges in the Rufiji - gaps identified

Despite the importance of the Lower Rufiji Valley to the nation's economy and well being, and the high potential for human use or natural events to adversely impact the area's resources and ecosystems, information about the status and trends, stocks, flows and interactions of critical environmental variables is dearth. Previous attempts to generate scientific information in the Rufiji have not yielded adequate information necessary for effective management of the complex issues faced in the Rufiji. These have either not been planned to allow for focussed research or have been too general, *ad hoc*, outsider-driven and not people oriented. Solutions have therefore not been generated while findings appear not to be made use of effectively. Integrated research is believed to provide the effective format for bridging science and policy as well as a vehicle for investigating the necessary linkages.

The research strategy presented in this Master Plan builds on a process that has been initiated to build partnerships and re-focus the traditional approaches to generating scientific information. This has been achieved by seeking the participation of both the scientific community in the country and the stakeholders in Rufiji in identifying information and knowledge gaps that integrated research can help to answer. In order for the overall goal to promote long-term conservation through wise use of Rufiji's forests, woodlands and wetlands in order to enhance the livelihoods and maintain ecological functions (ecosystem integrity) to be achieved, integrated research and monitoring is mandatory.

6.3.1 Conservation and sustainable utilisation of natural resources

The condition of ecosystems has not been described in temporal and spatial scales because of the absence of monitoring. The status and trends in resource use are incompletely documented, for instance the current and potential standing stock of and quantities of species remaining. This means that the "health" of ecosystems is not known. No quantification of direct and indirect use values of the support systems has been done, while ecological classifications and protocols for the river and floodplain have not been defined.

These gaps imply that the problems associated with the degradation of ecosystems and water resources have not been fully characterised, not to say in an integrated manner. The causes of existing problems are therefore difficult to diagnose, while the relationships among ecosystems' response variables and trade dynamics of various resources are not known. Incomplete (spatial and temporal), non-integrated studies have not allowed a clear identification of the parts of the system that are changing. As a result links and interactions within the systems and between the systems and people's activities have not been established with certainty. Forecasting and understanding of the seriousness of particular relationships or issues is thus nearly impossible at this stage.

6.3.2 Natural hazards management

Flooding is the heartbeat of the system in the Lower Rufiji, but even the nature of, and the extent floods and droughts is not fully described because of lack of monitoring. There is little understanding of the relation between rainfall in the catchment and the extent of floods in the plains. Characterisation of the problems associated with floods and drought is incomplete or controversial. Causes and consequences of problems associated with flooding regime, for example the risk avoidance strategy in agriculture by local people, are not articulated. The relationship between hydrological parameters and human induced changes in the catchment is not quantified. The relation between the river flow and water levels of the floodplain lakes is not known. There is little understanding of the interaction between the hydrologic regime of the river and nutrient dynamics of the floodplain soils. Analysis of the river regime and the risk assessment of the flood hazard have not been completed, and have not been undertaken in an integrated manner. This implies that adjustments to human activities as well as the technical adjustments required to feed in the analysis are not fine-tuned.

It has not been understood how current or potential human-induced changes in the landscape may alter hydrologic and bio-geochemical cycles. The lack of long-term measurements impedes the diagnosis of interactions and forecasting, for instance of the implications of reduced river flows and associated salinity increases on coastal ecosystems under various scenarios. The potential impact of such hydrologic changes on livelihoods is not understood.

6.3.3 Socio-economic development

Hydrologic-economic studies are lacking to define the environmental services associated with flooding. The conditions and trends in economic development at different levels (district, national) have not been described. The value of environmental goods and economic and non-economic incentives/disincentives for their exploitation/conservation has not been assessed. The existing and potential marketing strategies as well as alternative income generating activities should be explored

in detail. The marketing system and marketing operation are not known and this requires that a description is first made of market participants, market channels and market arrangements. Economic information on fisheries is lacking.

There is a shortage of research-based information available to decision-makers to evaluate alternative policies and assess their impacts. Analytical research (and not only a generalised community socio-economic studies which are primarily descriptive in nature) is lacking in such areas as costs and returns of fishing gear, economic efficiency of production technology, performance and efficiency of the fish marketing system, and political and institutional constraints. The linkages between biological, technological, economic, social and institutional factors remain to be identified and examined. Research can shed considerable light on the problems of low standard of living, by identifying and clarifying behavioural characteristics of fishers, loggers, logging companies, fishing communities, farmers etc, and by providing and defining alternative development and management solutions to decision makers.

Legal access potentials to natural resources (what is the best legal access to manage resources – property right regimes) are not known, while factors that contribute to poverty and economic insecurity are not identified in integrated ways (environment-poverty links). The problems associated with the current livelihood securities are only partially characterised. The causes of problems that have been identified and the interaction between environment and economic activities linked with natural resources use have not been adequately assessed. Quantification of economic benefits and costs of diverting water from the floodplain by building dams is lacking, and analyses of impacts of upstream development through flooding scenarios should be modelled.

6.3.4 Policy, institutional structures and legislation

Existing natural resource management policies are in need of review in order to update the link between policies (which are adequate) and legislation (which is outdated). Important knowledge gaps include:

- Analyse policies o environment and other policies that are related to the environment (these are…) and identify likely overlap and conflicts of interest. It has been realised that policies across the environmental sector have been relatively recently created (between 1992 and 1999), but without a strong institutional framework for environmental management sector. In addition, these policies have been created in the context where outdated and conflicting legislation still exists. Therefore, the question of the likelihood of effective policy implementation still remains. Reviews are required that would examine the Institutional and Legal Framework for environmental management (and in other areas of legislation)
- Few policies look at the totality of the environment, nor address the likely impact of one set of policy objectives on those of another policy, such that in some areas such as mining in protected areas, no policy exists. Neither do the land policy, the new forestry policy, nor the new wildlife policy recognise the exploitation of the country's mineral deposits (a valuable portion of which lie in what are currently protected areas). This policy vacuum makes it difficult to modernise associated legislation, much of which is outdated and some contradictory. This creates the potential for uncontrollable activities with environmentally damaging consequences (Local Perspective, 1998).
- The environmental policy gaps that exist are therefore more to do with the need to broaden the scope of the current policies rather than develop new ones. Research should contribute to this process by informing the policy formulation with relevant data.
- No policy framework exists for environmental data and information. Despite the large amount of environmental data and information that exists in Tanzania, there are considerable in its effective dissemination and utilisation. Research should contribute to this process by finding ways to effectively collect, disseminate and distribute environmental data. The process of information gathering should move away from the supply-led approach to information, and seek to meet the demand for data from decision-makers. Due to the fact that there is not a culture of demanding and using formal

information, whether by senior managers and planners or the general public and the media, the notion that "informed decisions are better decisions", has resulted in pressures of information overload in Tanzania Formal information plays a less significant part in decision-making. Therefore, research should investigate other factors (apart from) that still play a role in decision-making Tanzania. Furthermore, it is the role of scientists to produce updated state-of-the-art reviews and syntheses of existing scientific data and information and to assist in developing appropriate decision support systems and mechanisms such as GIS, Modelling, databases, early warning systems etc., which would make the information more accessible to, and transform existing information into usable formats for decision-makers.

- Existing opportunities for legal backing during implementation of management plans, strategies and action plans at district level;
- Interlinkages between natural resource management policies and other policies that affect natural resource management itself, such as education, health, tourism and trade;
- The role of various institutions as national regional district and village levels is not clear. For example little is known about the role of regional secretariats, sectors, research and training institutions, NGOs etc.;
- The general understanding of the relationships of local community, district and national level authorities who work together on common issues, and ways of benefit sharing remains wanting.

There is potential for integrating research efforts and forming partnerships that will enhance the decision making process or improve institutional capacity for research. However, no formal mechanisms for integration exist, making it impossible for institutions with different or overlapping mandates to collaborate. Furthermore, reporting and auditing complexities associated with funding give no incentive for integrating research efforts.

In short, the gaps (hence challenges for research) in the Lower Rufiji can be summarised as follows:

- Interdisciplinary, integrated systems research that cuts across priority issue groups;
- Research on effectiveness and economic risk for various policies, strategies and management practices;
- Knowledge generated by modelling;
- Knowledge generated by monitoring;
- Review of environmental linkages in the rural development and agricultural policies and the poverty eradication strategy.
- The research gaps that relate to the environment poverty link can be categorised in the following ways:
  - (i) Gaps in analysis (the extent to which poverty –environment linkages are properly understood and can be documented, by degree of poverty, regional basis and gender
  - (ii) Gaps in monitoring (identification of appropriate indicators at district levels as well as at national levels to reflect progress in activities undertaken within the framework of the poverty reduction strategy

7 Tools for monitoring and modelling

7.1 The need for monitoring

Monitoring is a continuing process which allows managers to identify changes and trends over time so that they can assess whether interventions are achieving the goals (in the case of biodiversity it is the conservation of key biological resources) and adapt management accordingly. It differs from general surveillance in that there is a specific reason and method for collecting particular data or information. Monitoring is not the same as measuring. Measuring of, say biodiversity provides a snapshot of biodiversity (e.g. the number of species present) at the time of the measurement. A monitoring programme should, ideally, be an integral part of a site specific management plan. It is however possible to implement a monitoring plan without the framework of a management plan, but it will be difficult to implement the results of monitoring effectively.

It is now widely accepted that ecosystems are constantly changing and research has its interest focussed on the processes behind these changes as well as the outcome of such change. A sampling programme should seek to address not just the question of "is there any change?", but rather – "what is the magnitude of change that is occurring; over what time scales; and what are the processes behind these changes?" Such questions highlight the need for robust monitoring programmes that provide unambiguous and interpretable results. It is also particularly important to define the spatial and temporal scales of monitoring activities.

Sustainable utilisation of resources and conservation involve ecological processes which are generally long-term (e.g. changes in numbers of a population of a key species) changes resulting from management interventions may be slow to emerge. Therefore, monitoring framework should extend long enough and if appropriate feed into a national monitoring system. The appropriate spatial scale of project monitoring will be determined by the specific goals and objectives of the management strategy/or project, and depend on where the focus is (in this case, the ecosystem and not landscape or species level).

7.1.1 Building the knowledge base through collaboration

In order for resource managers to be benefit from a monitoring programme, the latter must be able to detect and quantify any significant changes in the status of the resource. Monitoring is possible only after baseline data on various aspects of the environment have been gathered. First it is important to develop a knowledge base, information infrastructure, and a monitoring framework. For effective setting of a knowledge base collaboration is important. Effective collaboration will ensure that it is possible to achieve something that would otherwise be more difficult or more unlikely to be achieved. It also encourages the sharing of ideas or physical resources that ensure a better job (see chapter 10).

7.2 Prerequisites to developing a successful monitoring programme

The following questions should be considered:

1. Is there a monitoring goal or management objective or policy around which monitoring should be carried out? All monitoring programmes should have a defined goal. It is therefore worthwhile to define objectives rather than measuring everything in the hope that some of the data may provide useful information. It is likely that programmes will be limited by funding and logistic constraints, such that decisions have to be made about the intensity and extent of the programme. Therefore it is much better to have a monitoring programme that addresses fewer questions over a limited area and allows for repeated sampling over a number of years, rather than an extensive program which seeks to answer many questions over a large area with little replication. The objectives must be attainable and achievable within a reasonable time period. Finally, in outlining the framework and methods of predicting change in ecological character, managers should be primarily concerned with the *types* of change (grouped under biological, physical, chemical) as opposed to the *causes* of change (grouped under changes to

the water regime; water pollution; physical modification; exploitation of biological resources; and introduction of exotic species). Specifically they should be concerned with adverse change caused by human activity.

2. What is to be monitored? There is a variety of issues each with a variety of aspects to be monitored and these range from impacts of management action, trends in resource use/health, improvement in livelihood strategies, biodiversity. Aspects to be monitored may include landscape or species dynamics, socio-economic factors, community involvement and institutional and regulatory factors. No universal set of indicators can apply to all the aspects, thus specific indicators need to be chosen based on the objectives and goals (see section on indicators). The problems or issues must be stated clearly and unambiguously. The extent and most likely cause should also be stated. A baseline or reference situation must be identified.

3. Who is to do the monitoring? It is important to standardise measurements between researchers/observers. The goal and success of any sampling project depends on obtaining high quality data. Standardisation may be achieved through regular training of team members and comparisons with known standards and replication. The most important point to consider is ensuring that observer biases are not confounded with any other factors. That is, if two observers have different results, the difference should not be caused by the observers observing differently as it will be difficult to separate whether the data are different because they are different forests or because each observer records differently.

4. How is the monitoring data stored? All samples should be documented; date; names of staff; sampling methods; equipment used; means of storage or transport; all changes to the methods. All samples should be processed within a timely period and all data documented. Is a record of reports for various types of action kept and made easily available? There is no point in just collecting data. Data should be analysed to allow interpretation of the changes occurring. Information from data analyses allows for a review of the original design and consideration of the ability to answer the questions originally posed. Thus analysis should be an ongoing process, and not one that begins after many years of data collection. The analyses should be documented: date and location (or boundaries of sampling area), names of analytical staff; methods used; equipment used; data storage methods themselves. The identification of indicators and appropriate sampling regimes should take into account existing monitoring programmes and data sets as well as the capacity at both local and national levels. To minimise costs, data sources already available should be made use of as much as possible. In addition, those responsible for management of the Lower Rufiji area should be involved in the collection of monitoring data as much as is possible.

5. Does the monitoring programme function efficiently and effectively? Monitoring should be effective (meaning it has to lead to achievement of its goals) and efficient (meaning it does not consume disproportionate financial, managerial or time resources). Monitoring does not necessarily require sophisticated technology or high investment and can be carried out at different levels of intensity. There are many tools and techniques for monitoring. In general methods should be chosen that are appropriate to the human, financial and equipment resources available for the task.

In addition, records of financial costs of undertaking research activities should be kept, including collecting and making available information on the time required for such activities. This is important for keeping track of previous monitoring activities and may prove handy in developing further programmes.

7.3 Indicators as a monitoring tool

The most important aspect of any monitoring project is the choice of suitable and meaningful indicators. Environmental indicators provide summary measures or indicative phenomena that assists in environmental monitoring. They may be defined as *quantitative measurable elements*,

which contribute to the knowledge of environmental conditions and/or trends. Indicators can also be used to facilitate the integration of environmental and economic considerations in decision making. In addition, using environmental indicators makes it easier to communicate with the public, inform the policy dialogue, provide a basis for international co-operation and agree and measure/monitor environmental performance with respect to national policy and international agreements. Traditional poverty indicators include GNP per capita, immunisation rate, income/consumption distribution etc. Examples of environmental indicators would be (i) Mangrove area as an indicator gives an estimate of the area of the mangrove habitats and assemblages in estuaries, on the coastal fringes of the mainland and even on the offshore islands and dependencies where mangroves occur. To analyse and interpret Estimates of the area covered by individual assemblage types should be part of the analysis of the survey data. Changes in total area, and shifts in assemblage coverage, indicate major changes in environmental characteristics. (ii) mangrove species; (iii) fish stocks: This indicator documents annually for each of the top species (or species groups) ranked by dollar value, the total landed value, the total catch weight, an assessment of the stock and the formal status of the fishery; (iv) fishing effects on non-target biodiversity. This indicator documents the number of fisheries management plans that contain effective indicators for monitoring the level of, and extent of reduction in, impacts on non-target organisms, and the number of such indicators; and many more are available. Other traditional environmental indicators include forest cover, river flow, water, and oxygen content etc.

Nevertheless, there are those indicators that link poverty and environment, and these deserve to be given due consideration as the environment, the economy and the society interact in many ways to affect livelihood. Those indicators that link poverty and environment include forest loss, water quality, child stunting, household consumption, and more should be identified through further research.

For any monitoring project, it is important to choose a minimum set of few indicators that are feasible, useful and relevant to that project and can be sustained with local capacity and resources after the end of the project. Strategic planning should come first followed by the decision upon which of the indicators identified should be used. In the case of environment-poverty links, monitoring should then follow in areas that have been prioritized as areas of overlap between zones of high poverty and zones of potential environmental degradation.

7.4 Remote sensing and GIS as monitoring tools

The uncertainty faced in environmental management necessitates careful monitoring for changing environmental phenomena and the impacts of management interventions. Because of the range of environmental data and their continuous variability over time and space, this monitoring is especially difficult. Observation system may be built using various tools such as remote sensing (data collection) and geographic information systems (GIS)(enhances the processing and analysis of data). But only with changing and improved technology can the modelling of environmental systems and processes be made. GIS and remote sensing rely very much on technological innovation and development. Their utility for environmental managers may depend upon technology. However, the potential for their widespread application across a range of issues and problem areas in even less developed areas as the Rufiji exists. Examples of remote sensing techniques include air photography (suited for land use planning, resource inventories etc.) and radar scanning (suited for general overview over large areas and thus environmental monitoring over time). One way of applying remote sensing is, for instance, analysing a succession of Landsat TM data before and during a development in order to monitor its impact on forest, and wetlands. Also regional mappings, using GIS, can link poverty indicators with environmental profiles, which will assist in analysis of the importance of (drylands issues, fires, deforestation etc.) and resulting vulnerability.

Data collected and processed using these technologies allows managers to build up increasingly sophisticated models of the environment and to manipulate these models to test and evaluate the consequences of decisions on the environment.

For successful application of remote sensing users should realise that remote sensing is placed on the integration of multiple, interrelated data sources and analysis procedures. No single combination of sensor and interpretation procedure is appropriate to all resource inventorying and environmental monitoring applications. In fact, many monitoring problems cannot readily be solved by means of remote sensing at all. All designs of successful remote sensing efforts should involve, at a minimum,

- a clear definition of the problem at hand
- evaluation of the potential for addressing the problem with remote sensing techniques
- identification of remote sensing data acquisition procedures appropriate to the task
- determination of the data interpretation procedures to be employed and the reference data needed, and
- identification of the criteria by which the quality of information collected can be judged

If one (or more) of the above components of a remote sensing application is overlooked the results may be disastrous. A resource management programme must therefore have the means of evaluating the performance of remote sensing systems in terms of information quality. A capacity to interpret remote sensing data is mandatory, while a clear articulation of the information requirements of a particular problem and the extent to which remote sensing might meet these requirements is paramount to any successful application. In any approach to applying remote sensing, not only must the right mix of data acquisition and data interpretation techniques be chosen, but the right mix of remote sensing and "conventional" techniques must also be identified. Remote sensing data, not being an end in itself, should therefore be best applied in concert with others such as GIS, which permits the synthesis, analysis, and communication of virtually unlimited sources and types of biophysical and socio-economic data – as long as they can be geographically referenced.

It should however be realised that data collection and input are major problems in using GIS. Funding to acquire a system large enough to store considerable volumes of large-scale maps and parcel data should be secured. Good maps and land records are prerequisite, whereas base maps and data necessary for setting up a GIS system, are still absent. The system if set up ought to have a long-term objective, unlike the project-type, one-off systems used only for the research project and do not have a built in institutional arrangement to maintain the system after the project is completed.

Due to several factors which set practical limits to the amount of information that can be acquired and used, conventional aerial photography will remain the most widely used remote sensing procedure throughout the developing countries over other types. Such factors include the size and geographical setting of the country, the level of resource information already available, the capacity of the infrastructure to assimilate the information and make effective use of it, the cost of acquiring the information and the development objectives of the country. The Rufiji district has very few of the required resources necessary for sophisticated monitoring technologies and it thus follows that there will be continuing reliance on aerial photographs as an essential data base for resource analysis due to its proven worth, versatility and low costs.

7.5 Participatory monitoring: Local ecological knowledge

Local community involvement is important in establishing sustainable harvesting regimes for natural resources. Local villagers often have good knowledge of local environment and changing conditions over time. This knowledge can help determine appropriate indicators, refine sampling design, and interpret the results of monitoring. Often with minimum training and in a cost-effective way, local villagers can collect various data sets required for monitoring of biodiversity, resource use and environmental variables. For example fishermen already sample populations in their normal fishing activity, with consistent (perhaps) methods and equipment, thus it is more efficient to monitor their landings from specific sites to give estimates of yields from different lakes/other

areas. This could be done by fisheries administration, in collaboration with fishing co-operatives (if there are any).

Participatory monitoring is advocated here in the sense of "transformational" participation where the drive of the project/management strategy is that of achieving higher objective such as self-help and/or sustainability (as opposed to the "instrumental" participation where outsider targets are to be achieved through participation). When the community's perspective is paramount, the primary focus is the information needs of the communities while the secondary focus is on the information needs of the project. The timing of when to introduce participatory monitoring should therefore be considered carefully. It is best to adopt the concept of Participatory Monitoring and Ongoing Evaluation (Pmoe) (recording of useful information and periodically "breaking" to analyse the information that the community has determined to be important. Its key elements are directed and conducted for the beneficiaries, is systematic and consistent, is flexible, is locally relevant and balances between monitoring and ongoing evaluation correctly. Pmoe should also be based on key indicators that have been established by the community. These are selected by prioritising a number of relevant questions each of which substitutes for a "bundle of question" related to a specific issue. For example an evaluation team is responsible to gather information that responds to the "what do we want to know" statements that the larger group has listed. The questions that the team generates to address the statements are the indicators. Statement: We want to know why our stocking rates are below minimum.

Focus questions: (I) what are the current stocking rates? (ii) what was the condition of the seedlings when they arrived? (iii) Have external factors such as weather patterns created unusual conditions? etc.

Tools for participatory monitoring and evaluation can be selected from a range of instruments to be used to gather, synthesise, and analyse information in a way that is participatory. The tools should be selected with an open mind; they may have to be adapted and re-thought out to respond to each situation. They should be thought of, as "ideas" to be developed to respond to field reality. Many of the tools work individually to gather and analyse information, while helping to develop communication skills. An example of such a tool is drawing and discussion. Other tools are more specific, such as survival surveys. All of the tools, because they are developed with and for the community, serve also as extension and learning tools. Be flexible. If one tool is not working well, rethink it and suggest another one. Choosing the best tool for a situation is a unique and creative process. In order to assist in narrowing the choices of appropriate tools from the wide range of possibilities offered in literature as tools for Participatory Monitoring and Evaluation, one should consider their characteristics (e.g. visual, oral, written), main purpose (e.g. community problem analysis, participatory baselines, Pmoe, evaluation events), precautions in using the tool and resources required. The following are examples of tools available: group meetings, maps and mapping, community environmental assessment, survival surveys, participatory forestry action research, farmers' own records, community financial accounts etc.

Monitoring as an integral part of environmental management require adequate resources, including budget and institutional capacity, clear institutional responsibilities and reporting mechanisms. It is also important to build incentives and capacity to collect, use and maintain data for monitoring and evaluation.

7.6 Support systems for information management in the Rufiji

- Detailed techniques and protocols should be clear to observers at the outset, and once a certain technique is chosen, its use should continue unless there is evidence that it should be improved. Too many long-term data sets are made more difficult or impossible to interpret because of frequent changes to the methodology.

- Statistical advice to be sought in the early stages of a monitoring programme.

- A database management system should be developed during the pilot phases of the programme. A database should be an integral part of a monitoring programme. This is because databases enforce a set structure and thus helps to promote data consistency. Secondly, databases can deal with large amounts of data, and will help to reduce duplication. A number of features of databases help to ensure data quality, including data input screens that help inexperienced users; checking programmes that check for errors in the data; and the underlying structure of the database that promotes data consistency. Databases also form a gateway to other packages such as statistics and graphics software. Finally, the structure of a database forms the definition on which differing data sets can be joined, allowing data integration. Reference can be made to English et al (1997) for some guidelines in designing a database.

It is not just enough to input data into a data base system – the data must be managed. Data management includes procedures for ensuring that the data are entered correctly, that the database is described, and that the data are backed-up. There is no point in spending hundreds of dollars collecting data if the data in the database are not correct, or if nobody knows where it is or what it means. The following known principles of data management should therefore be applied:

- *Responsibility* should be assigned for various components of data management. Written procedures should be produced describing the steps for using and maintaining the database and detail the allocation of responsibility for each procedure. Once the people have been made aware of their responsibilities, setting and archiving data will become easier.

- *Data collection* is an important step in a monitoring programme. Factors to be considered when collecting data include the use of standard methods, which should be documented, and the use of data sheets to ensure all the required variables are recorded.

- *Data handling* is the next important step in data management. Procedures should be set up for allocation of sample identification codes (or indicators), data entry, data checking and validation, back-up and archiving of computer data and storage of the field data sheets and any collected specimen (in case of biological monitoring).

- There should be a concerted *awareness of data quality*. This is more than the sum of the data handling procedures but includes notions of accuracy, precision, repeatability of the field measurements and an awareness of the quality of data in the database. Thus data quality can be maintained by using set, written procedures for data handling, by being aware of sources of error, and by constant checking.

- The database structure and operation should be *described*. Components of full data description include: project handling, goals, and other details; description of sampling methods and design; and a short description of any software used, full programme listings of any programmes used for data entry and validation and a description of the computer systems used in the programme.

The use of a computer database is not a trivial exercise, particularly where large or complex data sets are being collected. There is requirement to develop expertise in database design and to put in place set procedures for all aspects of data handling and quality. The final outcome is that data is well managed and in the form that will integrate into other data sets.

- Hardware, including good quality aerial photographs or topographical maps updated (at regular intervals). For map production to be kept up, funds to purchase photographic printing and cartographic material is the most basic need besides training and retaining trained technicians in photogrammetry.

Data organisation, data availability, leadership, organisation structure and planning practice need to be built up. A wide-ranging collaborative framework with research and training components should be set up involving different research departments and external universities. Under such a

programme a GIS for resource utilisation and regional planning can be provided as a support system, but only with effective collaboration between institutions, as well as administrative co-ordination. Questions to be answered include how the data requirements at different levels (community, district, national) can be standardised or converted to a "consistent framework". This is an essential requirement in order to ensure that data are comparable and can be collated from different sources. With such a framework, data can also be organised and formatted for storage e.g. on CD-ROM. Moreover, the theoretical underpinnings for building a GIS at each level need to be reconciled as these are naturally different. To build a GIS, cost effective sampling procedures in data collection, and aggregations of disseminated data are required. Data should not have questionable statistical validity at various administrative levels, especially at the community level where the greatest detail in data availability is required. Nevertheless, the development of a GIS may introduce a new and improved approach for information systems for resource utilisation and regional planning in Rufiji and Tanzania at large.

As at now there is no standardisation of environmental data and little compatibility, unless by chance, between the various data storage and retrieval systems. The lack of policy and standards has resulted in databases being developed, usually as donor funded projects. Too often the "expert" has more technology expertise than experience in information management. There is a strong need for a network of linked compatible databases within Tanzania, especially with the currently improving telecommunications.

- Strategic alliances of co-operation and information sharing between industry, management and research

- Finally, research impact should also be monitored and evaluated as a condition tied to funding and whenever possible a long-term sustainability of research work/findings process. A programme may be developed to facilitate interactive communication (e.g. outlining how research results will be communicated to the managers). Communication efforts should be effective and should have room for improvement. Do researchers have links with user groups? How is research outcome promoted to users and community interest groups? How is the public made aware of research and education programmes (consider even media exposure). What is the extent of collaboration of users in all facets of the research programme? Is there commitment in material and organisational support by partners or members of a research team? Is the format in which research and monitoring results communicated effective? An updated set of performance indicators should be produced which provide certain criteria for performance of research. Such criteria may include:

<u>Research and researchers</u>
Questions to be asked to gauge the performance of research for researchers could include: Are participating researchers increasingly publishing in refereed journals? Are research results being presented (upon invitation) in other international scientific forum? Are researchers producing management tools (e.g. risk assessment models) or are they providing key information for strategic planning or any other information underpinning resource management (e.g. floodplain lake fisheries)?

<u>Application of research</u>
Questions to be asked in order to gauge the performance applied research may include: Are partners (those who collaborate in the formulation of research agenda for particular use) implementing environmental management products (such as tools for controlling invasive species) or using educational and informational products e.g. in tourism, fishery and logging industry? Is industry applying key research findings?

<u>Co-operative arrangements</u>
Questions that could be asked in order to gauge the performance of collaborators could include: Are core institutions involved in the research programme? Is Industry sufficiently involved in the

programme content and execution (e.g. providing and contributing to logistics and operations)? Does collaboration involve several research groups (e.g. from colleges, research, universities etc)?

Education and training

Questions to be asked in order to gauge whether research is contributing to education and training could include: How many graduate students are aligned with the research programme? Have any industry/community briefing workshops been conducted as an initiative of the research programme?

The major advantage of evaluating the impact of research is to be able to see how outputs from issue-driven research activities and outcomes of research products are being applied by the district resource managers and policy makers. It is the process of making science useful being made clear to all parties, but also reflecting the information needs of industry and management to better manage human activities in Rufiji District. Only then can new research help replace old dogma for instance innovative databases may begin to underpin commercial information for forest use and planning and to feed in to the resource use patterns in management planning for the District.

8 Assessment and reporting criteria

This chapter will give the criteria, which will have to be used to assess the adequacy of research proposals. It will also present a brief description of guidelines on publication and reporting.

8.1 Assessment criteria for proposals

Each funding agency has its own themes and geographical areas of interest. The proposals should therefore be written with the relevant information to be found in the funding agency's documentation. However, the Research Master Plan provides a strong backing for the proposal to the funding agencies. It is therefore important that the initial idea is chosen according to the research themes/issues outlined in the research master plan. The proposed project must have a clearly defined research/monitoring component and not just focussed on technology transfer or extension work. In the initial screening it is important to consider the following: Has the proposed work been (being) carried out in another region? If no, does the proposal meet strategic goals of the research programme, and is it in line with government policies over the issues presented? If yes, what aspects of the programme/project are applicable in this context. What are the existing/potential overlaps? There should be no duplication (of earlier research). Following this line of argument the proposal should contribute to:

- Closing the gap in knowledge identified in this research master plan
- Improving decision-making for sustainable development (see also outputs)
- Improving livelihood of local people and/or improving the conservation of biodiversity/ecosystem functioning.

Objectives should stipulate concern for natural resource and environmental protection (and if possible improvement), such that the concept of "development" is not restricted only to quantitative increases in output. Projects should incorporate the wise use/sustainable development concepts, which seek to "… satisfy today's needs without compromising the chances for future generations to satisfy theirs." Then a full concept, which is interdisciplinary, integrated research approach, preferring thematic above individual, single disciplinary, *ad hoc* study initiatives, should be set out.

Proposed project(s) should fit in the short-term, medium-term and long-term priorities (as identified in this report). The selected medium- and long-term objective of the project should reflect the way in which the expected results will contribute to solving important problems identified in the district (see chapter 9) and how the selected short-term objectives contribute to achieving the long-term objective. The scientific feasibility should not be doubtful i.e. the objectives should not be too ambitious considering the team's experience and training in research; or the objective is not realistic considering the resources available and the job environment. Certain programmes may need a very sophisticated scientific environment; or the objectives do not give heed to the socio-economic situation of the region. Although applicability of the expected results might be regarded by the applicant(s) as the foremost evaluation criterion, the experience of the applicants should not be neglected. The research capacity needs to meet the proposed study objectives.

In choosing the objectives, confusing the scientist's and the developer's objective must be avoided. That is to say, the project must be composed of scientific and technical elements and exclude political and economic considerations that are not incumbent on the scientists. For example, *the development of groundnut crops* is not a research target. It belongs under "development" operations supervised by various ministries and services. On the other hand, *identifying obstacles to groundnut production* within the region could be a research target. It follows that the scientist's objective on "hazards" problems identified should be more to do with aiding in their prediction as opposed to solving the problems.

Working hypotheses is the next step to organising a work plan and it consists of splitting each specific objective into working hypotheses. A hypothesis is a process of scientific reasoning that consists of an assumption that is proven through its consequences. Each objective is analysed in

terms of the path leading to it, the steps to be taken; the resources, and the observation work. There may be several roads that lead to the objective, so several hypotheses may be involved. Then set out cost and time scale, resources and inputs needed to apply the appropriate methods for testing the hypothesis with reasonable chance of success. Is time allocation against tasks realistic? Is task allocation against budget sensible?

Clearly specified outputs (and how these will contribute to closing the gaps in knowledge) and performance indicators/criteria/evaluation of research effectiveness/impact should be spelled out. This should include the appropriate format for information synthesis and dissemination/communication and application of research results. For example scientific papers with a wider distribution should be encouraged, but also "WI-style reports" newsletters?, press releases/information sheets …

Local research institutions favoured above outside research proposals – where appropriate, strategic alliances between institutions (local, national/international) should be given priority.

A proposal may be accompanied with a narrative that contains clarity of concept/argument in accordance with the principles outlined in the research master plan. It should demonstrate the capacity of the team to do the job and have a clear need statement, project description including evaluation, budget, and fact sheet for the applicants. As for the layout the proposal is expected to contain reason, logic and substance. Data must be extracted in such a way that it is easy to get through and be readable.

8.2 Reporting criteria

The scientific team that accepts outside funding commits itself to making its work public. Funders normally demand three types of reports i.e. financial, technical and summary. The financial report will obviously be guided by the rules of the funding agency itself. We will concern ourselves with the technical and scientific reports in this section.

All the facts and figures from observation work and measurements made for the project are put in a technical report. This means everything, including unsuccessful and lost trials, negative results etc. This report is normally bulky since it will contain tables and figures that may cover several pages, and it may never be used (except by another scientist who may wish to repeat the experiment). But the full technical report is necessary and should be produced in a few copies to the centres of documentation, libraries and individuals' copies. All results should be interpreted and reported in a timely and cost-effective manner. All reports should be concise and indicative whether or not the hypothesis has been supported. Reports should contain recommendations for management action, including further research and monitoring.

The scientific report on the other hand contains the conclusions of the work plan, supported by the main and most significant results. The author should refer to the aims of the project and try to draw a conclusion in relation to the working hypothesis described earlier. The scientific report should be drafted as if it were a manuscript to be published in a journal. This is usually constructed to include an introduction (that describes the context and hypothesis); a presentation of materials and methods, a discussion of results, and a conclusion. Many scientists do however forget acknowledgements! Such a structure is preferable in disseminating results to the wider scientific community. Efforts should be made by the scientists to ensure that their results are actually put to use by asking themselves the following questions:
- Will the results of our work be used?
- How can we get our results used more?

It is important to avail research reports for decision-makers in a language and format that is easy to read. Research results ought to be distributed with the aim of having feedback from the communities. The technical outlet, scientific journals, is a handicap in communicating to managers, but still provide a wider and more sustainable distribution than bulky technical reports.

To reinforce the establishment of a communication pathway for exchange of information (IUCN 2001), technical reports produced should be distributed to the Rufiji district council members, scientists, tourism operators, libraries and academics. This should make up the basis of the final task report. A requirement that those copies of every technical report produced are delivered to TANRIC, and at the Reference and Document Centre (earlier proposed to be at the Ministry of Water, River Basin Management and Small-scale Irrigation Improvement Project (RBMSIIP) is necessary.

Regardless of the duration and scale of any research/monitoring task, technical reports should not be the only end product. But other communication and extension activities should be encouraged for example, fact sheets on collaborative research issues for stakeholders and interest groups. Feature stories of the scientific programme should be contributed to a range of other high profile and popular journals, newsletters and trade magazines. Research results should also feature in the regular Rufiji Basin Newsletter ("Rufiji Basin News" facilitated by WWF and JET) and the Rufiji web site. These channels will ensure a wider distribution of research reports, media releases, feature stories and scientific papers.

8.3 Utilization and application of research

Perhaps the district management should:

- Facilitate communication and extension in order to promote interactive communication with key stakeholders and distribute research results, besides input into policy and assisting stakeholders identify and solve problems concerning sustainable use of the Lower Rufiji resources;
- Organise joint seminar programmes by researchers to present their work to partners, advisory committees, district management and other community groups to discuss research findings; and workshops to plan and disseminate research information on the Rufiji to managers, fishers, tourism operators, and other stakeholders;
- Organise joint Rufiji Basin displays on Wetlands and Environment days (and other such festivals) including information kits and school competitions, posters etc.;
- Encourage media and parliamentary release papers, which may help to narrow the gap between scientific research and policy making.

In order to secure sustainability and ownership of the results of research and monitoring, participatory research as well as community involvement should be encouraged such that research is demand-driven and feedback and accountability become a part of the research strategy. NGOs should seek involvement in research and monitoring efforts. Research and monitoring programmes on the basis of this master plan should assume continuously increasing knowledge of how ecosystems function and respond to anthropogenic forces. Equally important is an appreciation for the values and needs of the Rufiji people and the capabilities and interests of the institutions that will play roles in the management process.

It is important that a productive relationship between scientists and managers is sustained so that both parties work to achieve:

(1) A common support for the goals and objectives of the programme, which should include choosing attractive formats to present and disseminate findings, besides scientific publications as well as summarizing the findings of the research programmes in final executive reports (the format and attractiveness of which should be guided by the direct value and relevance of the data for environmental management and conservation, rather than following scientific jargon and protocols).
(2) A mutual understanding of the respective pressures and reward systems under which scientists and managers operate.
(3) A long-term commitment to progress of the programme, which may also seek to link up with regional or global initiatives on integrated river management and/or coastal and marine conservation and management (e.g. through the Nile Initiative, UNEP, World Conservation

Monitoring Centre etc.) to make research findings and recommendations from these programmes available to such exercises and

(4) A continuous output of information and progress reports (in the form of feedback) so that all parties are aware of decisions and events affecting the course of the programme). Programmes may engage in regular consultations with representatives of management and conservation initiatives and authorities for feedback and fine-tuning of research focus and management approach.

Such a relationship may require a structure that should help to achieve results. Informal inter-institutional working groups (or teams) on specific issues identified in this master plan is one of such structures. Scientists with interest will then participate as individuals while the emphasis should remain that of problem solving, finding areas of common interest and collaborative action.

9 Summary and priority research subjects

9.1 Theme 1. CONSERVATION AND SUSTAINABLE UTILIZATION OF NATURAL RESOURCES

Goal: To understand levels of sustainable use of Rufiji's natural resources that would alleviate poverty whilst preserving biodiversity: ensure optimal and sustainable use of the area's natural habitats without compromising the biodiversity or functioning of the area.

Issue	Objective	Research Activities
1.1 Over-exploitation versus sustainable management of natural resources	To improve the capacity to determine ecologically sustainable levels of resource use	*Short-term priorities:* - assess fish stocks, CPU & catch statistics in river, lakes, delta - assess standing stock, pole cutting & timber dynamics of mangroves & woodlands - examine issues relating to indigenous hunting & fishing with regards to extent and economics, social context and cultural values - quantify illegal & destructive resource use & impacts on ecology/socio-economy - monitor impacts of improved infrastructure/access on resource use - investigate the status of mangrove and other forest resources in general - estimate sustainable yield (in volume terms) of mangrove cutting in delta *Medium-term priorities:* - fish breeding biology & recruitment rates of target and by-catch species - impact of trawling/harvesting methods on fishable stocks - relationship between human population dynamics & perceptions on resource use - review and analyse sources of unsustainable use practices (including demands from outside the area, property right institutions and systems of control, which create disincentives for wise use of natural resources) - Study life histories and population dynamics of selected major target species and monitor and evaluate trends in fish population parameters - Monitor and evaluate trends in catch/effort ratios for major fisheries (esp. in lakes & delta) *Long-term priorities:* - sustainability of legal hunting - effect of management use options on the status of mangroves - carrying capacity of forest ecosystems & potential use of non-timber species - holistic analysis of trade-offs between development and conservation, esp. addressing demands for resources for which alternatives exist + decision- & policy-making process on large-scale developments - impact of infrastructural development on resource use particularly forests and woodland - predict forest depletion levels (consider external harvest and local population increase)

Issue	Objective	Research Activities
1.2 Use support systems (ecosystem function)	Improve the capacity to determine the functional relationships between the ecosystems and the natural resource use potential in the Rufiji river, floodplain & delta	*Medium-term priorities:* - fish species diversity, habitat use and migration patterns - relationship between fisheries and the flooding regime - quantify links between flooding (hydrology) and natural resources - quantifying direct & indirect use values of mangroves (delta) - lake hydrodynamics (& links to river flow) and related productivity (incl. fisheries) - upstream-downstream linkages - understand the dynamics of the natural forests e.g. growth and yield characteristics, ecology and hydrological processes - estimate direct and indirect use values of different natural habitat types in the area - quantify in economic terms the role of wetlands as buffers or sponges *Long-term priorities:* - food-web studies relating to fisheries - impact of habitat management (incl. protected areas) and habitat changes on fisheries - understanding mangrove forest dynamics (incl. regeneration) - impacts of climate change on (support) ecosystems - models to identify gaps in our understanding of ecosystem function/change
1.3 Biodiversity conservation	To improve the basis for selecting areas to be given a high level of protection	*Short-term priorities:* - survey & map current status of wildlife populations & their habitats - identify biodiversity hotspots and conservation priorities within Rufiji area - Compile a comprehensive inventory of the natural and, as appropriate cultural resources of the area and patterns of use *Medium-term priorities:* - human-wildlife conflicts - identify ecological monitoring protocols & biological indicators of environmental quality - develop decision support systems to optimise the selection of protected areas using the inventory as a basis *Long-term priorities:* - wildlife & eco-tourism potential - assess impacts of habitat fragmentation on biodiversity - monitor habitat changes, e.g. modification of habitats and disruption of predator/prey- and other ecological relationships
Issue	**Objective**	**Research Activities**
1.4 Degradation of eco-	To quantify the nature &	*Short-term priorities:*

systems and water resources	extent of human-induced ecosystem capacity to predict recovery from such disturbances	- study impacts of rice cultivation in mangroves on ecosystem/human health - patterns and transport mechanism of contaminants used in rice farming in the delta and their effect on living resources *Medium-term priorities:* - impact of trawling on benthic habitats recovery dynamics of trawled habitats - study minimum (fresh)water requirements of mangroves in delta - links between revenue collection strategies and degradation of forests & other natural resources - analyse historical effects of demography and land use activities on ecosystem health - food chain linkages between floodplain lakes and the river, including effects of various types of fisheries on food chains *Long-term priorities:* - identify & test optimal schemes for management of secondary forest areas

9.2 Theme 2. NATURAL HAZARD MANAGEMENT

Goal: To understand how the Rufiji River affects ecosystem functioning; the relationship between flooding, the ecosystems and habitat dynamics, the plant and animal communities, and how all these are impacted by human activities

Issue	Objective	Research Activities
2.1 Flood management	To quantify the nature & extent of effects of floods & flood-control measures on ecosystems & improve the capacity to predict recovery from disturbances caused by flooding events	*Short-term priorities:* - measurements to extend vertical and meteorological coverage in data available - monitor water levels & river flow, frequency & extent of floods - quantify physical transport of sediments, nutrients and pollutants - study of sedimentation processes and baselines on inputs (quantifying rates & types) *Medium-term priorities:* - impacts of changes in river flow (due to upstream abstraction, dam construction and climate change) on flood-dependent ecosystems (incl. habitat alterations) - analyse hydrological information from EIA's under different development scenario's - monitor upstream rainfall patterns and predict effects of climate change - analyse hydrological information gathered by EIAs under different development scenarios - impact of land management in the catchment area on floodplain, lake & mangrove soils - predict implications of salinity increase with reduced freshwater input due to dam construction
Issue	**Objective**	**Research Activities**
		Long-term priorities: - collate data on timing & extent of floods to build water balance model for the basin - predict impacts of flood-control works on livelihoods & fisheries in lakes/floodplain/delta

		- assess economic impacts of water diversion and flood control interventions - understand hydrological functioning in delta, floodplain and upstream catchment - impact of upstream land use changes/impoundments on downstream flux of materials and marine receiving waters - statistical predictions of inshore and offshore fisheries production after dam construction - predict impacts of dam construction on down-stream agricultural production
2.2 Drought and famine management	To investigate the effects of droughts and famine with a view to reducing their impacts on the livelihoods, economy and ecosystems	*Medium-term priorities:* - document catastrophic events and alteration of estuarine habitats due to floods/drought - Investigate the impacts on livelihoods, the economy and the ecosystems of the area *Long-term priorities:* - temporal trends due to regional/global (extreme floods and droughts, climate) changes - impact of regional/global changes on forestry, ecosystems, agriculture & livelihoods
2.3 Fire management	To investigate the effects of fires with a view to reducing their impacts on livelihoods, economy and ecosystems	*Short-term priorities:* - analyse the frequencies, patterns, causes & people's perceptions/motives to fires - impacts of various land use practices (esp. burning) on land and soil conditions *Medium-term priorities:* - study fire ecology and the impact of fires on forests and floodplain ecosystems - identify and test fire-preventative measures - document the impact of fires on regeneration/seedling recruitment of valuable forest species, species diversity and physico-chemical characteristics of soils - effects of fire-stress on ecosystem functions with emphasis on cumulative impacts of spatial and temporal changes *Long-term priorities:* - determine the impact of slash and burn practices on land use and land degradation - projected changes as a result of management of land use activities in the area

Issue	Objective	Research Activities
2.4 Invasive species & vermin management	To investigate the status and effects of invasive species and vermin with a view to reducing its effects on ecosystems and agricultural production	*Short-term priorities:* - assess status of invasive species in lakes, river, forests, woodlands & estuarine habitats - human-wildlife conflicts (crop damage etc.) *Medium-term priorities:* - examine links between invasive species and the ecology of habitats in the floodplain, delta and lakes - assess impact of vermin attack on agriculture - identify and test vermin control strategies *Long-term priorities:* - study impacts of invasive and introduced species on ecosystems/biodiversity - identify suitable control programmes for taking action against invasive species - Tse-tse flies ?

9.3 Theme 3. SOCIO-ECONOMIC DEVELOPMENT

Goal: To understand the reasons for the prevailing socio-economic conditions; analyse economic opportunities, capabilities and security and their relation to environmental conditions and to find alternative livelihood strategies for the Rufiji people

Issue	Objective	Research Activities
3.1 Poverty and economic insecurity	To improve the capacity to understand the underlying causes and to develop appropriate measures to alleviate poverty	*Short-term priorities:* - understand the value of Rufiji's natural resources to local communities (incl. food security) (also in comparison with the cultivation systems with which they are replaced) - assess the value of the area to regional and national economies - improve the understanding of lifestyles and livelihood security options that exist - describe current agricultural systems and practices (esp. risk reduction strategies) - describe trade routes and marketing chains of natural resources - understand constraints to agricultural production (despite floodplain soil fertility) - investigate most suitable small-scale irrigation methods for different sites & purposes *Medium-term priorities:* - impacts of decisions on large-scale development in the area on local livelihoods - impacts of decisions on large-scale development in the area on national interests - understand how shifts in national economic strategies are affecting livelihoods in Rufiji - political-economic study on the historical impact of Ujamaa policy on present land care attitudes and tenure
Issue	**Objective**	**Research Activities**
		- investigate human & social capital issues (attitudes towards borrowing, credit, investments; membership to

		groups, constraints to collective endeavours etc.) - thorough investigation of the relationship between agricultural production and profits *Long-term priorities:* - develop alternative sources of income to reduce pressure on fish & forest resources - research to develop ways to increase added value of natural resource products and improved marketing - develop ways to reduce the opportunity cost by providing alternative use of time, land, etc. - monitor the effects of changes in health issues on agricultural production - predict the impact of infrastructure development on livelihoods in the Rufiji - research ways to increase quality, quantity and diversity of agricultural production (esp. increased profits to local farmers), incl. alternative soil management systems
3.2 Links between poverty, environment & education	To improve the capacity to determine the linkages between poverty and environment	*Short-term priorities:* - quantify the economic advantage of introducing mechanisms to ensure wise use practices regarding resources that are no longer abundant - economic valuation of the mangrove resource including nursery function for fisheries - investigate the causes of low enrolment and high drop out rates in schools *Medium-term priorities:* - encourage the development of economic approaches to valuing: (i) major biological communities subjected to varying levels of impact (ii) major uses of the area as required - provide well presented data on environmental services - impacts of land degradation/habitat reclamation on socio-economic development - impact of illiteracy and innumeracy on resource degradation - anthropological studies into features sustaining people-environment interactions - study trade dynamics of target species (high value timber, bush-meat and selected marine products (e.g. shrimp, sea cucumber, octopus, shells, etc.) and benefit distribution *Long-term priorities:* - understand the links between the areas biodiversity to human welfare - monitor the impact of the current national poverty alleviation strategy on the environment - quantify links between natural resource use strategies & poverty & unveil root causes of poverty

Issue	Objective	Research Activities
3.3 Economic versus environmental vulnerability	To improve understanding of the vulnerability of the local socio-economies	*Short-term priorities:* - characterise trends in population size and migration patterns within the district
		Medium-term priorities: - undertake economic studies on the value of alternative uses of key resources and selected biological communities - impact of migration patterns on access to social services - impact of emigration on the local economy
3.4 Communication gaps	(i)To establish an information knowledge base for the area & for its ecologically sustainable multiple use (ii)To establish feedback mechanisms between research, management and people	*Short-term priorities:* - establish a publicly accessible network of systems for storage, retrieval and dissemination of existing and newly acquired, non-confidential information relevant to the area - improve the understanding on cultural & historical influences on attitudes & perceptions in natural resources management - understand people's values and attitudes towards environmental issues - identify perception gap between promoters of any development & perceived beneficiaries - improve the understanding of the causes of constraints in information flow within & without Rufiji *Medium-term priorities:* - develop mechanisms for sharing and accessing data and information and for coordinating and rationalising research effort - develop methods for the analysing, interpreting, communicating & applying research results *Long-term priorities:* - disseminate results of research, monitoring & applications through refereed publications, management recommendations and extension materials (incl. statistical figures, maps and other formats that simplify research/monitoring results to stakeholders at various levels - develop culturally-appropriate/understandable formats for regulatory & informative materials that is distributed to people in Rufiji

Issue	Objective	Research Activities
3.5 Impacts of large-scale development & environmental interventions	To review and predict the effects of large-scale interventions on livelihoods, economy and Ecosystems	*Long-term priorities:* - review lessons learnt from interventions in river floodplain & delta's elsewhere in the world - monitor the impact of awareness campaigns on values and expectations of different groups - decipher the social ramifications of various decisions; how the Stiegler's Gorge dam construction might affect downstream agricultural production, etc. - cost-effective analysis of dam construction on macroeconomy

9.4 Theme 4. POLICY AND LEGISLATION

Goal: To examine (as a case study) the constraints to effective implementation of national policies and legislation with regards to environmental management and sustainable development

Issue	Objective	Research Activities
4.1 Constraints to effective policy implementation	To examine the impact of NRM (and related) policies and legislation on natural resource use and environ-mental management	*Short-term priorities:* - review relevant legislation to identify inadequacies, unnecessary duplication and anomalies - review policies for natural resource management (do they have the desired effect?) and links & overlap between NRM and other policies (e.g. health, education, tourism, trade, etc.) *Medium-term priorities:* - evaluate the role of various institutions at regional, district and village levels (e.g. regional secretariats, sectors, research & training institutions, NGO's etc.) - assess the effectiveness of implementing institutions against environmental & related policies - identify existing opportunities for legal backing during implementation of management plans, strategies and action plans at district level *Long-term priorities:* - research socio-economic aspects of inter-sectoral issues related to use & management of the area's resources - identify best legal access/property right regimes to manage natural resources - evaluate impact of national policies on the observed trends in resource use
4.2 Decision-making process	To improve the capacity to enforce legislation per-training to the management of natural resources efficiently & effectively	*Short-term priorities:* - understand how ecological services and functions are valued in the decision-making process *Medium-term priorities:* - examine how the different management options are evaluated to select the best - examine the relationships between and identify mechanisms for the coordination and benefit-sharing between local communities, district- and national administrative levels *Long-term priorities:* - develop indicators to evaluate the human response to management decisions (incl. their willingness and efficacy to behaviour change)

10 Funding Strategy and Institutional Cooperation

10.1 Fund-raising plan

Consideration and agreement of budgets will depend on individual proposals that will result from the research master plan. However, phased budgeting for the programme is recommended. For example, a preliminary budget could be adopted to allow the scientific research for baseline assessment and monitoring to be initiated in advance of other programme elements.

One of the first steps that should be taken to contact donors is to survey existing funding opportunities to identify sources. In relation to such a survey, reference could be made of the environmental grant-making foundations (such as the ones listed in the 1993 directory of the Environmental Data Research Institute, New York).

Some of the potential sources to be explored for research funding may include:

- Marine Science for Management (MASMA) which is a new regional programme administered by the Western Indian Marine Science Association (WIOMSA) and Coastal management research Management Center (COMREC) of the Sodertorn University College, Stockholm and funded by the Swedish International Development Agency (SIDA);
- SAREC Marine Bilateral programme and the new SAREC basic science support;
- WIOMSA (e.g. MARG grants);
- WWF-Ecoregions Russell E. Train Education for Nature Programme;
- COSTECH;
- Tanzanian Government funding including how the implementation of PRSP may affect Tanzania government funding for research;
- IFS grants;
- RAMSAR small grants Scheme; and
- PEW Fellowships, etc.

Once funding sources have been identified, proposals can be written using the master plan as a guideline. Meanwhile copies of the research master plan should be sent around to potential donors for their information as means to place Rufiji on their maps and give a "screening" criteria or a pre-idea of important research areas. They may indicate/express areas of their interest, which they would like to support. A seminar can then be organised to present the plan to potential donors and ask for their feedback. The master plan could also be sent to the KNAW for consideration to develop a Netherlands/Tanzania scientific co-operation Programme. In this way, fund raising efforts for research institutional departments could be on the one hand augmented by a strong justification of an existing opportunity to contribute to the National Research and Development effort owing to the principles and objectives set in this master plan. It is imperative to sell the master plan to various research institutions especially those that have participated in the development of the plan (locally and internationally) so that wherever appropriate Rufiji may be put on the map of as many research agendas as is possible. On the other hand departments that include Rufiji in their research agendas can channel acquired funding for research and monitoring in the Rufiji.

Funding may be considered either of the whole of the Lower Rufiji (e.g. Lake Victoria Environmental management project or Lake Tanganyika Biodiversity), or chopped up in pieces with the themes identified as a background. The Master Plan should be seen as a strategic umbrella framework from which parts can be taken and considered for individual projects/funding…

Private sector support for research (e.g. TANESCO, Tourism hunting agencies, SELOUS, SONGO-songo gas pipeline, Domus and other furniture industries…) should not be overlooked. However, care should be taken to ensure that private sector support does not imply a free ticket to overexploitation of resources, but should be a genuine contribution towards sustainable development and environmental health conservation through its support to research efforts.

10.2 Co-operation between institutions and research teams: the basis for fund-raising

This research master plan has been developed through consultation of various institutions in the hope that the parties/stakeholders involved at different levels can safely consider the master plan as a reference document. Participation contributed to making available the information that was essential, but otherwise not forthcoming, and also to identifying important issues from a wide range of disciplines. The participatory process is hoped to have created a sense of commitment to and hopefully a continuing involvement with this initiative.

While it remains critical to increase the capabilities of management institutions, additional information on the status of the resource, people who use the resources have had little opportunity to contribute to the planning and implementation of management strategies, and that has resulted in poor acceptance of management legislation. Relevant institutions (both research and management) and communities need to see the need to (collaborate so that, with appropriate methods, they can) contribute significantly to the information base that is necessary for management. Furthermore, they can set the stage the implementation of management strategies by involving all the actors not only in making management decisions but also in collecting data on which they are based.

Memoranda of understanding, joint integrated research programmes and informal working groups are some of the structures that may enhance such collaboration. International research institutions should involve Tanzanian counterpart institutions (ICLARM, JGOFs, ICRAF, ILRI, CIFOR + research institutions (chapter 2) at all stages of the research programmes. In addition, research partnerships of local institutions should seek involvement/interest of universities outside the country (e.g. WL Delft hydraulics in The Netherlands, Stockholm University in Sweden, Free University of Brussels, University of Antwerp in Belgium, Catholic University of Nijmegen, in the Netherlands etc.) preferably within framework of existing collaborative programmes. Through multidisciplinary and interdisciplinary research, such as has been proposed for the Rufiji, the intricacy of networking for international co-operation should be boosted. Without democratic consultation and interaction based on sensitive, efficient and effective co-ordination, the key concept of having national and international partnerships becomes difficult at best and unworkable at worst.

The demands of scientific research are normally high: more money, more trained and skilled manpower, more equipment, more training programmes, both formal and informal, more scholarships, more overseas attachments, and greater commitment on the public to the development of scientific capacity. However, often expensive equipment, including research vessels are provided through donor agencies while problems of maintenance or recurrent budgets prevent its proper use. Partnerships ought to learn from such experiences to avoid perpetuating the practice. The philosophy of partnerships should be executed in a more open way being less oriented towards inheriting research material only but also the transfer of know-how. Effective collaboration will allow for the sharing of existing infrastructure and equipment (and specific skills/staff/expertise).

Collaboration will usually lead to appropriate information gathering due especially when potential strategic alliances of co-operation are formed between industry, management and research (Industry here includes for example, tourist operators, commercial fisheries, forest logging companies etc). Interdisciplinary collaboration between biologists, integrated river planners, ecologists, engineers, geographers, economists, business managers, zoologists, statisticians, social scientists, communication professionals, and research teams and organisations lead to the gathering of information that enhance the understanding in such a way that can help better decision making/management. Furthermore collaboration may ensure better research planning of focussed work aimed at generating solutions. The participation of stakeholders also enhances information sharing and the acceptability or use of results. Besides ensuring availability of relevant/experienced researchers (i.e. if research is not planned, relevant people are busy elsewhere.) overlap/duplication is avoided as research becomes more cost-effective through good planning. Research effort may be

better rewarding if researchers form and work in teams around the themes identified in this master plan.

10.3 Research infrastructure capacity

10.3.1 Human resources capacity building

Research should include, where appropriate (strong) training components, leading to improvement of the national curricula system. In order to carry out quality research in Rufiji, research institutions need qualified personnel,
There should be a training needs assessment for research institutions. Such an exercise should include tasks and duties and search for problem areas of weak performance, solvable through training (as opposed to (i) constraints to job execution that can be solved through other means (ii) subjects and topics). The nature and causes of performance problems is appraised to identify training needs. The focus should be on jobs not on individual persons doing the jobs.

Clear guidelines/expectations between both the trainers and the trainees should be established in cases where researchers and technicians are sent abroad for training. Previously people have been sent abroad for training without effectively identifying where the real need for training lies. Hands-on training tied to programmes if encouraged will allow new knowledge to be put into practice.

Infrastructural capacity building

An adequate infrastructure (including equipment) and the capability to maintain it is a prerequisite for quality research. Dumping of outdated/old equipment by partners ought to be discouraged.

Information and communication technology infrastructure

Information storage (databases), use and management need to improve before new information is gathered. Besides, manipulation and supply of research results to users, information exchange and improved awareness on the value of and communicating information require serious attention both locally in the Rufiji region as well as nationally. Strategic scientific research programmes, information and information systems, together with an holistic approach to the science, based on its being accorded high status at a national level, are necessary if research and monitoring results are to feed into management requirements. Joint research efforts organised in research themes rather than disciplines can help to achieve this.

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12 Annex 1.

Scientific institutions and research centres interested in the Rufiji

This chapter will describe past, present and future national and international scientific institutions that are involved or could be encouraged/attracted to become involved with the Rufiji, including the scientific and management committees that can commission, support or carry out short to long term research activities. The institutions described below have been involved in one way or the other in the process that preceded the development of the research master plan for the Rufiji floodplain, delta, forests and woodlands. It is important that the scientific community be involved in the development of the plan in order to take forward the process of building partnerships in the Lower Rufiji area. Such partnerships would help to answer immediate research questions and, in the medium and long term, will constitute the basis for research in support of environmental management in the district. By involving the decision makers in the identification of priority research needs, it is hoped that the Rufiji district will build up linkages necessary for the backstopping of management decisions and for the continuous adaptations of the Rufiji District's Environmental Management Plan as would be recommended by observed changes and/or new research findings.

The University of Dar es Salaam (UDSM)

The University of Dar es Salaam was established out of a decision taken on March 25th, 1970, by the East African Authority, to split the then University of East Africa into three independent universities for Kenya, Uganda and Tanzania. The University of Dar es Salaam consists of six faculties, five institutes and two colleges: The Faculties of Arts and Social Sciences; Commerce and Management; Education; Engineering; Law; Science; the Institute of Development Studies; the Institute of Kiswahili Research; the Institute of Marine Sciences (IMS); the Institute of Resource Assessment (IRA); the University College of Lands and Architectural Studies (UCLAS) and the Muhimbili University College of Health Sciences. The University also operates a Computing Centre, a Library and four bureaux: the Economic Research Bureau in the Faculty of Arts and Social Sciences; the Bureau of Educational Research and Evaluation in the Faculty of Education; the Bureau of Industrial Co-operation in the Faculty of Engineering and the University Consultancy Bureau.

The Institute of Marine Sciences (IMS)

IMS was established in 1979 and is based in Zanzibar. IMS activities are oriented towards understanding, managing, utilising and conserving marine and coastal resources. It undertakes research in all aspects of marine sciences (living resources and ecology, chemical and environmental marine science and physical and applied marine sciences). The institute also provides postgraduate and undergraduate training and advisory and consultancy services in coastal and marine affairs. IMS plans are charted out in its five-year strategic rolling plans that are updated on a yearly basis. IMS also enjoys good research co-operation with other marine research institutions in the Western Indian Ocean Region, Europe and Australia.

Institute of Resource Assessment (IRA)

The Institute of Resource Assessment, formerly Bureau of Resource Assessment and Land Use Planning (BRALUP) was set up in July 1982. BRALUP was established in 1967 as a research wing to the University College of Dar es Salaam. Its main activities were to conduct applied research and offer consultancy services in various fields. Some of the current IRA activities are a continuation of BRALUP activities but with modification in approach and emphasis. Its overall objective is to address the whole question of sustainable development. The main areas of research include agricultural systems, population and human settlement, water resources and natural resources and environment. Remote sensing is an important sub-area that services all the research activities. The major efforts of the institute are directed to the development of its research capacity and providing professional advice. IRA maintains important links - in terms of research, training and capacity

building - with various local and international organisations in Sweden, UK, Denmark and the Netherlands.

University College of Lands and Architectural Studies (UCLAS)

The University College of Lands and Architectural Studies (UCLAS) became a constituent college of the University of Dar es Salaam on July 1, 1996. It was originally founded in 1956 as a survey training school, located at Mgulani. The school was strategically moved to the Observation Hill (its current location) in 1958. In 1972, it became Ardhi Institute and offered tertiary level education in land surveying, rural planning and land management and valuation. Later on architecture, building economics and environmental engineering were added. The long-term perspective of UCLAS is to become independent, catering for graduate and undergraduate as well as advanced diploma courses. The college has two faculties, one institute (Institute of Housing Studies and Building Research (IHSBR) and continuing education and a geo-information centres.

Sokoine University of Agriculture (SUA)

Sokoine University of Agriculture was established on 1st July, 1984 by Parliamentary Act. The University was created from the former Faculty of Agriculture, Forestry and Veterinary Science of the University of Dar es Salaam. The university has four Faculties and six Directorates/Institutes: the Faculty of Agriculture; the Faculty of Forestry and Nature Conservation; the Faculty of Veterinary Medicine and the Faculty of Science; the Institute of Continuing Education (ICE); the Developmental Studies Institute (DSI) and the Directorate of Research and Postgraduate Studies (DRPGS). The University also operates a Computing Centre, a library (Sokoine National Agricultural Library (SNAL)) and a Centre for Sustainable Rural Development (SCSRD).

Tanzania Forestry Research Institute (TAFORI)

The Tanzania Forestry Research Institute (TAFORI) was established in 1980 by Act No. 5 of 1980 which gave the institute the mandate to co-ordinate research in forestry carried out within Tanzania mainland. Apart from co-ordination, the institute also carries out research and disseminates research results to end-users. TAFORI has developed a national forestry research master plan (NAFORM) for the years 2000-2009. The master plan gives a background on forestry research in Tanzania and sets priorities and outlines research strategies on forestry issues in the country.

The National Tree Seed Programme (NTSP)

The National Tree Seed Programme was established in 1989 to respond to the deforestation in Tanzania that stands at an estimated 400,000 ha annually. The physical structure of NTSP consists of National Centre (NC) situated in Morogoro, and three zonal Seed Centres. The tasks of the NC include carrying out applied research and development into problems of seed handling (phyto-sanitary problems, storage conditions, pre-germination treatments, etc.), flowering phenology, basic seed improvement and others. The programme also involves itself with various other activities including promoting tree improvement activities relevant to seed procurement, documenting tree seed requirements arising from the combined afforestation and tree planting activities in Tanzania; publishing technical/research notes, manuals and annual reports of all aspects of seed procurement and facilitating applied tree seed improvement and gene resource conservation.

TRAFFIC

TRAFFIC is the wildlife trade-monitoring programme of WWF-World Wide Fund for Nature and IUCN-The World Conservation Union. TRAFFIC works in co-operation with the secretariat of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Its mission is to ensure that trade in wild plants and animals is not a threat to the conservation of nature. It was founded in mid-1970s largely to assist in the implementation of CITES, which now covers over 30,000 plant and animal species. TRAFFIC is now a network of 21 offices (including Tanzania) organised in seven regional programmes. While continuing to support the application of CITES, TRAFFIC has developed its role in addressing wildlife trade issues in a wider context,

including major commercial sectors such as fisheries and timber trade and a wide range of regional and local issues. TRAFFIC's programme priorities are threatened species, priority eco-regions, resource security and international co-operation. One of TRAFFIC's conservation methods is mobilising knowledge by researching to ensure that decision makers acquire and apply sound knowledge about the scope, dynamics and conservation impact of wildlife trade and its response to different management measures.

Tanzania Fisheries Research Institute (TAFIRI)

TAFIRI was established in 1980 with the aim of promoting, conduction and co-ordinating fisheries research in the country and disseminating research findings to government agencies, public institutions and private companies engaged in the fishing industry. Its research priorities are fisheries statistics and fish stock assessment, fish biology, fish diseases, fishery management, fish processing and marketing, water pollution and aquaculture.

National Environment Management Council (NEMC)

The National Environment Council was created in 1983 by Act of Parliament of 1983, and became operational in 1986. It is responsible for the formulation, co-ordination and evaluation of policies and legislation related to environment. The council is also responsible for monitoring and assessing the state of the environment in relation to development activities, and has commissioned several coastal and marine environmental studies. One of its functions is to collect and systematise the scientific and environmental information.

The Tanzania Commission for Science and Technology (COSTECH)

The Tanzania Commission for Science and Technology was established in 1986 by Act of Parliament No. 7 as a successor to the Tanzania National Scientific Research Council established in 1968. The Commission is an apex body for the co-ordination, promotion and popularisation of Science and Technology in Tanzania. In order to fulfil its promotional role the commission supports Research and Development activities within the priority areas of the Commission through its research grant facility. The grants may be granted fully or in collaboration with other granting agencies.

COSTECH has the mandate to oversee research done by other research bodies and co-ordinates a total of eight (8) statutory (specialist) committees. These committees are composed of representatives from different sectors (e.g. agriculture, environment, industry and energy etc.). In this regard any scientific and management committee that could be formed either to commission, support or carry out short- to long-term research activities in Rufiji should liase with COSTECH.

Tanzania Coastal Management Partnership (TCMP)

TCMP was created in 1997 through a consultative study, which highlighted the need for an overall framework that supports coastal management at local and national levels. It is a co-operative initiative between the government of Tanzania through NEMC, the United States Agency for International Development (USAID) and the Coastal Resources Centre (CRC) of the University of Rhode Island. Partners address coastal management issues and facilitate the foundation for coastal governance. The TCMP works with the existing network of integrated coastal management (ICM) programmes and practitioners to promote a participatory process to unite government, community, science and management, and sectoral and public interests to conserve and wisely develop coastal ecosystems and resources.

Frontier – Tanzania Project

The project started in 1989 as a collaborative research effort between the Society for Environmental Exploration (UK) and the University of Dar es Salaam. Frontier is a not-for-profit conservation organisation. Research is conducted by a number of volunteers on a variety of habitats in Tanzania's coastal zone, chosen for their biological interest and conservation value. Studies are

developed with the assistance and collaboration of Regional and District Authorities and the Ministry of Natural Resources, Tourism and Environment. Research concentrates on baseline surveys of habitats and associated flora and fauna, fisheries and resource user assessment; mangrove species survey and mapping; birdlife surveys and tidal cycle and current analysis.

Western Indian Ocean Marine Science Association (WIOMSA)

WIOMSA is a regional professional, non-governmental, non-profit, membership (inter-disciplinary) organisation, registered in Zanzibar, Tanzania. The Association provides a forum for communication and exchange of the information amongst its members that promotes and fosters inter-institutional linkages within and beyond the region. It also supports marine research by offering research grants and implements programmes to build the capacity of marine scientists and coastal management practitioners. WIOMSA works to promote policy dialogue on key topics by organising meetings and seminars on the findings and policy implications of science.

Other institutions

Numerous research institutions based externally to the region (principally in Europe, but also in the US, Australia and more widely) may have long-term involvement in research in the region. International institutions/structures that could commission, support or carry out research in the Rufiji include SIDA/SAREC; ECOMAMA Programme (VUB Belgium); International Centre for Research in Agro-forestry (ICRAF); Centre for International Forestry Research (CIFOR); ICLARM, IMWI, IRD, CIRAD etc.