The Leverhulme Trust

APPLICATION FOR A RESEARCH PROGRAMME GRANT 2003-2004
COVER SHEET

SUBJECT AREA

(2) WATER, LIFE AND CIVILISATION

Applying Department and Institution	School of Human & Environmental Sciences and the Department of Meteorology, University of Reading
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Title of research programme	Climate, water and civilisation: model predictions and evaluations

Duration	5 years	**Estimated total budget**	£1,215,500

CLIMATE, WATER AND CIVILISATION: MODEL PREDICTIONS AND EVALUATIONS

1. Introduction

The inter-play between climate and water availability has been fundamental to human activities in the past and will continue to be so into the future - nowhere more so than in the semi-arid regions of Middle East and North Africa (MENA). It is in the great river valleys of this region – the Jordan, Euphrates, Nile and Indus – that the ancient civilisations arose, while the plight of this region under a changing climatic and hydrological regime is central to global ecology, economics and politics today.

This project will assess the changes in the hydrological climate on past, present and future human activities within this region using state-of-the-art climate, crop and hydrological models, and by bringing together a unique suite of researchers from the University of Reading including meteorologists, crop scientists, hydrologists, geologists, sedimentologists, archaeologists and geographers. The project will have two levels: first, the development and evaluation of a climate model, including crops, for this region as a whole; second, the development and evaluation of a detailed hydrological model for the Jordan Valley, using this as a specific case study for the interplay between water, life and human society throughout human history into the present and the future.

It is within the Jordan Valley, that the first farming communities arose at 10,000 BC, soon followed by the first towns such as Jericho. For more than three millennia these towns housed the largest aggregations of people on the planet until they dramatically collapsed around 6500 BC. Throughout the later prehistoric and historic periods the Jordan Valley was the scene for further social and economic developments, including the great Nabatean trading settlements, Roman and Ottoman settlement. Social and economic change remains on-going today with an increasing intensification of agriculture, the settlement of formerly nomadic people, and the development of industry.

The one resource at the centre of all such past and present activity is water, its status changing from a natural resource to a cultural commodity and having now become a resource at the centre of political tension. Many models of social change and development are based on assumed environmental causes but yet, curiously, the nature of the hydrological cycle and river flow within the Jordan Valley has not received the academic study it requires. Nor has there been adequate study of how the hydrological regime has impacted on past settlement and how it might do so in the future in the context of global climate change and further economic development.

2. The proposed nature and emphases of the research programme

The project will bring academics at the University of Reading into integrated programme of research over a five-year period beginning on 1 October 2005. At the centre of the programme will be the construction and evaluation of state-of-the art climate model for the MENA region as a whole. This will constitute a high resolution (100km) global model with an embedded regional model (~25km) for the MENA region. This will enable the development of an integrated climate and hydrological model for the Jordan Valley to allow the detailed examination of one specific area of the MENA region for key dates in the past. The combined system will be tested for the present-day and will be used to describe changes in water availability and its impacts for the coming century. Specifically the following time periods will be considered since global climate model simulations already exist or are planned for these periods.

- 20,000 BC – the time of the last glacial maximum when the Jordan River and Lake Lissan (future Dead Sea) were at their lowest levels for the past 100,000 years and human settlement consisted of highly mobile hunter-gatherers.
- 6200 BC – The farming towns of the PPNB are dramatically deserted between 6500-6000 BC, leading to the development of a nomadic pastoralist lifestyle. The reason for their abandonment

remains unclear and largely unexplored. Climatic events and environmental degradation are likely to be contributing factors, both closely related to changes in water flow within the valley system.

- AD 150 – In AD 106 the Emperor Trajan annexes the Nabatean Kingdom that had flourished in the southern region of the Jordan Valley. He established *Provincia Arabia* of the Roman Empire and a system of forts was developed to protect imperial estates and control the desert and semi-urban settlements in the valley. These resulted in a substantial population increase and major developments in water management.
- AD 1750 – In the Medieval period the Jordan Valley was an important resource competed for by Crusader and Muslim forces. The Mamluks continued to expand activity within the valley, most notably by initiating the sugar industry. Major refurbishment of water mills occurred during the Ottoman period, but increasing aridity may have been a major factor in the decline of the region during the early modern period. There is, however, no direct environmental evidence to support this often quoted assumption.
- AD 2003 - The present-day situation in the Jordan Valley is one of a falling water table and competing demands for an ever reducing water supply coming from industry, farming and tourist developments. Major water management projects have taken place on the western side of the valley, while these are beginning in the eastern, Jordanian side. These combine physical measures, such as dams and pipelines, which generally reduce flow into the area, and international agreements. The latter may produce increases in the short term through the amount of water permitted to flow through such rivers as the Yarmouk from Syria, or in the longer term with various plans for major water distribution systems.
- AD 2100 – Future water flow within the Jordan Valley is a key issue for social and economic development of the region. The impact of current water usage and global warming on water supply are currently unknown and can be explored by the application of a climate-hydrological model that has been tested, calibrated and evaluated by the application to past situations. The impacts of changes in the water supply on cropping systems in the MENA region will be explored.

In addition the following periods will be a focus of archaeological study and may be used for climate simulations if resources allow.

- 9500 BC – the beginning of the Holocene. This saw significant increases in global temperature and rainfall. The first settled human communities appear, designated as those of the Pre-Pottery Neolithic A (PPNA) period. By 8000 BC these had become flourishing farming towns (PPNB) cultivating cereals and herding goats.
- 3000 BC – The appearance of the substantial Bronze Age settlements, that some describe as the first urban communities of the Jordan Valley. These had social hierarchies and were the first communities in the region to develop significant water management projects.

The simulated hydrological cycle and river flow for each of the key dates will provide the framework for a suite of research projects in archaeology and sedimentology. The emphasis of the project and location for fieldwork will be on the eastern, Jordanian side of the valley as this is where several of the most significant archaeological developments occurred, where issues about economic development are most pressing, and where the project can feasibly be executed in the current political climate of the region. In this regard, its Jordanian base will be the Council for British Research in the Levant that has a research institute in Amman.

The climate modelling will focus on a broader region than just the Jordan and will consider the past and future changes in the hydrological cycle for the MENA region. The importance of understanding how climate will change for this region has been emphasised by the World Climate Research Programme as a key area for action.

3. Project aims

The project will provide a comprehensive understanding of the past, present and future relationships between water and human settlement in the MENA region with a specific focus on the Jordan Valley. It will make a seminal contribution to:

- the understanding of past water availability and the consequent major changes in human settlement from 20,000 BC to the present day;
- the ability to simulate present day hydrology in semi-arid regions of the MENA and to evaluate its impact on human activity;
- predicting future changes in water availability for the MENA region and hence the constraints under which social and economic development, particularly agriculture, must occur.

4. Component projects

The project will have five component parts consisting of two models, one for climate and one for hydrology, and studies concerning palaeoenvironments, the history of human settlement, and the current and future patterns of land use. All studies will make extensive use of existing published data. When necessary, carefully targeted fieldwork will be undertaken to acquire new palaeoenvironmental and archaeological samples for analysis, and collect data regarding current human activities. In essence, the combined climate and hydrological models will provide predictions for the water cycle and river system for each of the key study dates. The predictions will be evaluated using palaeoenvironmental data and implications used to enhance interpretations of the archaeological and historic data. This process will enable a refined climate-hydrological model to be developed for the prediction of future water resources in the MENA region and specifically for the Jordan Valley. The consequences for human activity will be assessed by the developmental geography studies drawing on the present character and forces of economic and social change.

4.1 Climate Model

Aim: to predict annual and seasonal changes in climate for the MENA region and to evaluate the simulations using locally derived climate proxy, archaeological and geographical data. The output from the climate model will feed into the hydrological model for the Jordan Valley.

Method and sources: The NCAS Centre for Global Atmospheric Modelling will use the Hadley Centre's state-of-the-art HadGEM1 model at high resolution (100km) for decades at the specified periods in the past and present. The global model will provide the boundary conditions for nested regional models of the MENA region and the Jordan Valley. Projections for the future will be based on the Hadley Centre scenario runs and those being performed at CGAM through other projects as part of the UK's contribution to the next Intergovernmental Panel for Climate Change (IPCC) assessment. Evaluation of the present day climate model rainfall estimates for semi-arid areas of the MENA region would be carried out by direct comparison of modelled rainfall against archived raingauge and satellite-based rainfall estimates using appropriate statistical techniques and by comparing modelled and observed rainfall as inputs to hydrological and crop growth models. These models have already been developed as part of other projects and will be important in assessing the ability of the climate model to simulate realistic hydrological and agricultural conditions.

Lead researchers:

Professor Brian Hoskins FRS: Royal Society Research Professor and Professor of Meteorology, specialising in the understanding of the motion of the large-scale atmosphere.

Professor Julia Slingo: Director, NCAS Centre for Global Atmospheric Modelling, specialising in climate modelling, climate variability and change, and crop modelling.

Dr David Grimes: Lecturer in Meteorology at the University of Reading with expertise in hydrological monitoring and validation.

Professor Bruce Sellwood: Professor of Applied Sedimentology at the University of Reading with expertise in palaeoclimatology and process sedimentology.

Summary of Resources required:

One 3-year post-doctoral researcher for development of regional climate modelling for the MENA region and Jordan Valley, performance of integrations for key dates in past, present and future; one 3-year post-doctoral researcher for analysis of present day hydrology and model evaluation; one 3-year post-doctoral researcher for analysis of global and regional integrations including links to the integrated crop modelling. £100K for computing costs.

4.2 *Hydrological model*

Aim: to predict the spatial and temporal variations in water flow regime and salinity of the Jordan River system at each of the study dates in light of the climatic, environmental and land use factors.

Method and sources: Hydrological, meteorological, salinity and land use data from the Jordan River Basin will be collated and used to develop a hydrochemical model of the Jordan system that can simulate flow regime and salinity levels. Several hydrological modelling approaches are available including process based models such as INCA and stochastic time series approaches. The most likely to be used is INCA, a catchment rainfall-runoff and chemical mass balance model which can be used to investigate the impacts of land use change and climatic change. Simulations will be developed for the current flow and water quality and calibrated and tested with hydrological salinity data from the Jordan River system. Simulations will then be constructed for the specified study periods and for past and future climatic and land use conditions in the valley. The GCM climate models will provide the driving variables for the INCA hydrological and salinity model.

Lead researchers:

Professor Paul Whitehead : Professor of Physical Geography, University of Reading, visiting Professor at Imperial College London with expertise in theoretical and applied aspects of environmental hydrology and control, river basin modelling and water quality management.

Dr Andrew Wade: Senior Research Fellow, University of Reading, with expertise in catchment hydrochemistry, acidification and nutrient modelling.

Summary of Resources required:

1.2 Postdocs per year for the duration of the project; £15K sub-contract to Dr R. Manley (Water Resources Associates) for collection and provision of essential hydrological data for the River Jordan System; travel and consumable costs.

4.3 *Palaeoenvironmental studies*

Aim: to reconstruct prehistoric, historic and modern landscapes to interpret river flow regimes (and hence water table, fluvial power and flow dynamics), sedimentary deposition and vegetation history of the Jordan Valley area. The palaeoenvironmental evidence will be used to test the predictions of the climate and hydrological model outputs, and then refine these models to produce more accurate predictions for the past, present and future.

Methods and sources: (1) The sedimentological history of the Jordan Valley will be assessed from published data and from new field studies. A key requirement will be undertaking of ultra-high resolution dating of sediments and vegetation units (pollen) of the modern (< 100 years old) fluvial system (using short-lived isotopes in the U-series chain and ^{14}C) in order to test the modern climate-hydrological model. These data, along with the tested climate-hydrological model outputs, will then, for the first time, be overlain on a GIS system to produce a coupled, climate-hydrological-sediment-vegetation feedback data set to infer water balance model in the region and to provide the parameters for the new model of the region; (2) to undertake high-resolution dating of key sequences (AMS-^{14}C, TL and U-series) of pollen, charcoal, fine-grained sands and continental carbonate- and sulphate-rich deposits (Dead Sea) to create a chronostratigraphy and vegetational history for the Jordan Valley area

including the Dead Sea coastline. These data will be important in testing the climate-hydrological models of the past (as above) and a GIS feedback data set will be constructed for each time slice. Sampling for these will be critical and will be collected from the region at new sites already identified, and from known sequences (e.g. The Hula Basin). In addition, a study of the micro- and macro-botanical remains from the archaeological sites and palaeoenvironmental contexts will also be undertaken to link human activity into the feedback data sets.

Lead researchers:

Dr Stuart Black: Lecturer in Environmental Radioactivity with specialist expertise in U-series dating of arid-zone environments.

Dr Petra Dark: Lecturer in Environmental Archaeology with specialist expertise in the pollen analysis and the interpretation of archaeobotanical remains.

Dr Kevin White: Senior Lecturer in Environmental Remote Sensing specialising in fluvial and aeolian processes.

Summary of Resources required:

One 3-year Postdoctoral Research Fellow (U-series, TL and ^{14}C dating together with construction of the modern and past GIS system (ARCInfo) feedback datasets; 1 3- year PhD studentship (vegetational history of the Jordan Valley region using pollen sequences) and macro-plant remains from archaeological sites. Travel and consumable costs.

4.4 Archaeological studies

Aim: to develop our understanding of the history of human settlement within the Jordan Valley, of the methods used to manage water supply, and of the changes in human health and diet from pre-farming to the modern day. Interpretation of the archaeological evidence will be conducted in light of the output from the climatic and hydrological models and the palaeoenvironmental studies.

Method and sources: (1) The radiocarbon chronology for human settlement will be re-assessed and developed by the construction of a new data-base of existing samples, the application of new calibration curves and the strategic acquisition of new samples for dating from current and previous archaeological excavations. (2) The history of water management will be documented and analysed by collating evidence from archaeological sites and documentary sources for the use of springs, wells, cisterns, terracing, reservoirs, dams, conduits and water lifting devices. (3) The history of human health and nutrition will be assessed by the analysis of skeletal samples from the specified time periods for pathological conditions and by chemical analysis of human bone.

Lead researchers:

Professor Steven Mithen: Professor of Early Prehistory specialising in Early Neolithic settlement within the Jordan Valley and the origins of agriculture.

Dr Anne Pirie: Lecturer in Archaeology, specialising in late Pleistocene hunter-gatherers of the Middle East.

Dr Bill Finlayson: Director of the Council for British Research in the Levant with expertise in the prehistoric and historic settlement of the Jordan Valley.

Summary of Resources required:

One 3-year PhD studentship for development of a radiocarbon chronology for prehistoric settlement in the Jordan Valley; one 3-year post-doctoral researcher for the documentation and analysis of water management within the Jordan Valley from prehistory to the current day; one 3 year post-doctoral for the palaeo-health and diet analysis of human remains. Travel and consumable costs.

4.5 Developmental studies

Aim: to understand the current and future interactions between industrial, agricultural and tourism development on the eastern side of the Jordan Valley and their impact on water usage and supply. This will be undertaken in the context of new schemes for water management being introduced by the Jordanian Government and predictions from the climate-hydrological model. Studies will also be undertaken for how the use of sewage and other water waste products can be used for agricultural irrigation.

Methods and sources: (1) Field surveys and inventories of the growth and development of the industrial, agricultural and tourism-based demands for water. (2) Field survey and inventories for the growth of informal sector settlements and associated water use and supply issues; (3) semi-structured interviews with key decision makers regarding water policy; (4) cost-benefit type analyses of the provision of water to various users; (5) analysis of how the water and organic matter within sewage and water waste can be used effectively while avoiding contaminants such as metals.

Lead researchers:

Professor Rob Potter: Professor of Human Geography at the University of Reading since 2003, and previously professor of geography at Royal Holloway, University of London, with expertise on planning and settlement evolution in developing countries.

Professor Stephen Nortcliff: Professor of Soil Science, with expertise on the flow of water and solutes through soils in temperate and tropical environments.

Summary of Resources required: One 3-year post-doctoral researcher for the land usage study and one tied PhD studentship for the waste-water usage study, travel and consumable costs.

5. Anticipated form of the dissemination of research results

- Peer-reviewed papers in academic journals
- Annual workshops and concluding project conference at the University of Reading and at the Council for British Archaeology in Amman
- Dedicated website
- Final monograph publications for academic community
- Book publication for non-specialist readers

6. Information on relevant research under way at the University of Reading

This project brings together several areas of international excellence at the University of Reading and a suite of academics with extensive, relevant previous experience. Climate modelling will be undertaken by the Department of Meteorology (**Hoskins, Slingo, Grimes, Sellwood**) (RAE 5*) which is a world leading centre for research in atmospheric and climate science and location of the Centre for Global Atmospheric Modelling. Hydrological modelling (**Whitehead, Wade**) will be undertaken by the Aquatic Environments Research Centre (AERC) within the School of Human and Environmental Sciences (SHES). AERC conducts multi-disciplinary research on the structure, function, problems and management of a range of aquatic environments funded by EU, DEFRA, DTI, NERC, the EA and private companies. It has extensive experience of environmental modelling in semi-arid areas such as Zimbabwe, Tunisia and Egypt. Palaeoenvironmental studies will be undertaken by staff within the Archaeology and Geography departments of SHES. **Black** has 10 years' experience in working on U-series dating of arid-zone environments. **Dark** has similar experience studying late Pleistocene and early Holocene pollen sequences and plant remains from European sites, and **White** has undertaken field-based studies in Libya, Egypt, the Kalahari and southern India. All three palaeoenvironmental researchers have been supported by funds from the major research councils, notably NERC. Archaeological studies will be undertaken within the RAE 5* rated Archaeology department of SHES. **Mithen, Finlayson** and **Pirie** have extensive experience of fieldwork in the Jordan Valley with major projects funded by the BA and AHRB. **Potter**, undertaking the Development studies, has more than 20 years' experience of studying planning and settlement

evolution in developing countries. **Nortcliff** has extensive worldwide experience and knowledge of soil science, acknowledged by his appointment as Secretary General of the International Union of Soil Sciences.

7. Project location and management

The project will be based within the School of Human and Environmental Sciences at the University of Reading. This School was formed in August 2002 by an integration of the departments of Archaeology, Geography, Sedimentology and Soil Science so as to facilitate inter-disciplinary teaching and research. Hence it is ideally suited to undertake this project with eleven of the fifteen lead researchers being based within the School, three others being located within the Department of Meteorology with which the School already has substantial academic collaboration. Professor Steven Mithen, as Head of School, will act as co-ordinator of the five project components and ensure that the necessary facilities are made available. The project management board will be constituted by five of the lead researchers (Mithen, Sellwood, Whitehead, Hoskins and Potter) and five non-participatory senior academics, two from the University of Reading and three from other institutions. The project will also be affiliated to the Council for British Research in the Levant with the CBRL's Director, Dr Bill Finlayson, acting as a member of the management board as well as one of the lead researchers.