Centre for
Water Informatics
and Technology (WIT)

# Spring School on Water Systems, Science & Practice
# Lahore University of Management Sciences

## Module 2: Systems Analysis: Applications to the Water-Energy-Food Nexus

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### Description

Population growth, socio-economic development, and global warming and climatic pattern changes pose significant challenges for adequately meeting the needs of water, food, and energy in the country. Pakistan's agriculture and energy are significantly dependent on the water resources of the Indus Basin. However, the basin is poised for large-scale changes as a number of hydro-power dams are under-construction and several more are planned. Furthermore, trans-boundary new dams (such as those planned in Afghanistan), water diversion (such as in India) together with climatic pattern changes and glacier mass loss may adversely affect water availability in Pakistan, Additionally, agricultural production has not kept pace with growing domestic needs. Potential future reductions or irregularities in water supplies can adversely affect crop production and food security of the country. The issues of water, energy, and food security, however, are not independent but intimately linked. For instance, increase in agricultural production may cater for food needs but at a potential cost of increased ground water exploitation together with increase in energy consumption for pumping and production of fertilizers. These factors adversely affect ground water quality, land-cover changes, bio-diversity and overall regional eco-system. New infrastructure planning and operation of existing systems requires new approaches for maximizing inter-connected objectives while effectively addressing future environmental uncertainties. This module will introduce key concepts of systems theory, systems analysis, optimization and applications for quantitatively and qualitatively analyzing critical linkages between water, energy, and food systems that are vital for effective policy making and sustainable management of natural resources.

### Objectives

This module will provide an introduction to systems analysis, optimization methods and applications to analyzing water, energy, and food inter-linkages and tradeoffs. The module will enable participants to: (i) understand key concepts important for systems research and management; (ii) understand major concepts of optimization methods, multi-objective decision making, and tradeoffs; (iii) understand critical contemporary inter-linked challenges of water, energy, and food security in the Indus basin. This module will introduce novel methods for academic research as well as new concepts that can be employed for management and policy in water, energy, and agriculture sectors in Pakistan.

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**Session 1: Introduction to Systems Analysis (Afreen Siddiqi)**

This session will introduce concepts of systems theory, systems modeling, and key analytical methods for natural and engineered systems. An introduction to optimization for engineering planning and management, and linear optimization methods will be provided.

**Session 2: Multi-objective Decision Making (Afreen Siddiqi)**

This session will focus on multi-objective optimization methods. An introduction to continuous and discrete optimization, non-linear optimization, trade-space analysis, pareto optimal solutions, and decision analysis will be given using eamples from water infrastructure planning, hydropower systems.

**Session 3: Applied Systems Analysis: Water – Energy - Food Nexus (Afreen Siddiqi)**

This session will discuss how water, energy, and agriculture systems are interlinked and the implications for meeting the needs for water, energy, and food requirements for a growing population. A brief overview of how the conceptual paradigm of the water-energy-food nexus historically developed, and an overview of methods for studying system inter-linkages in water, energy, and food domains will be provided. A case-study of the energy-water nexus in irrigated agriculture in Punjab will be presented. The case study will show how number of increase in tube-wells has increased ground-water extraction, enhanced agricultural yields, but at the cost of increased energy consumption concomitant with groundwater pollution due to increase in fertilizers use. In an energy-stressed region, there are trade-offs in agricultural production, industrial production, and other sectors. The substitution of diesel with solar energy will be discussed, along with the question of how to reduce overall energy consumption, over-exploitation of groundwater resources etc. An overview of publicly available datasets from bureaus of statistics, ministries, and local departments will be given.

**Session 4: Water-Energy-Food Nexus: Global Perspectives, Practice, and Future Research (Afreen Siddiqi and Asif Khan)**

In this session, a number of recent examples from international cases will be provided to show how different countries are approaching the inter-linked challenges of water, energy, and food. Examples will draw from a number of perspectives including resource interconnections, governance, and integrated planning of resources across different stakeholders and government agencies. The regions will include Europe, Middle East and South Asia. Examples of UN Sustainable Development Goals (SDGs), current challenges in natural resource management and use, Key knowledge gaps of system interactions in the Indus basin, and key questions for policy and management will be discussed.

**TARGET AUDIENCE:**

The session is designed for a general audience as well as for academics with a basic knowledge of water resources, agriculture, energy, and environmental sciences. The session could be of benefit for graduate-level (Masters, MPhil and PhD) students. In addition, the session would be beneficial for professionals in water and energy trans-boundary issues, environment, climate change, ecosystems and biodiversity, water governance, hydro-power construction, green energy systems, solar powered water pumping, and related areas. The topics will be relevant for those interested in learning about basic concepts of systems analysis, natural resource governance and management, and infrastructure planning.