Integrated management of wetland ecosystems using a dynamic systems approach (case study: Anzali wetland)

Madineh Kakavandi[1], Hossein Mostafavi*[1], Mohammadreza Nazari[1], Alireza Shahmohammadi[1], Zhaleh Amini[2], Houman Liaghati[1], Mahdi BadriFariman[3]
[1]Shahid Beheshti University, Environmental Sciences Research Institute, Iran
[2]Department of Environment, Iran
[3]University of Birjand, Environmental Sciences, School of Natural Resources and Environment, Iran
*Email: hmostafaviw@gmail.com

Shahid Beheshti Universiti

Introduction

A non-ecological approach to wetland ecosystem management has created numerous challenges for these habitats, particularly in Iran.

Objectives

To analyze the current condition and challenges of the Anzali Wetland. To develop an integrated qualitative conceptual model at the watershed level for well managing wetland ecosystems, designed to be applicable to other wetlands in the future.

Methods

The study area was the watershed of the Anzali Wetland in Iran.

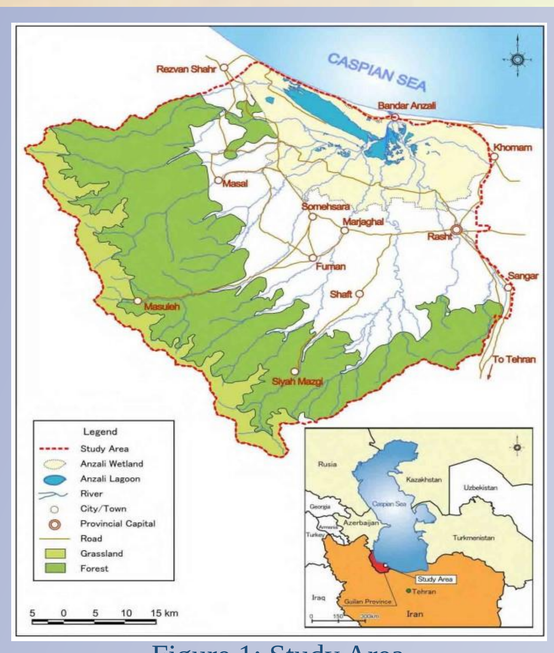

Figure 1: Study Area

Abiotic components

Parameter	Value	Unit
Wetland Area	195	km²
Average Wetland Rainfall	1,303.3	mm/year
Average Temperature	16	°C
Average Annual Evaporation	872.3	mm/year
Annual Inflow Discharge	1,750.59	million m³/year
Average Annual Sediment Volume	119,200	m³/year
Water Depth	1.5	m

- **Biotic components:** 21 mammal species, 254 bird species, 71 fish species, and hundreds of plant species.
- **Threats :** Climate change, Caspian Sea water level reduction, Pollutant Inflow i.e. the discharge of urban, agricultural, and industrial wastewater into the Anzali Wetland leads to an excessive growth of plants and microorganisms, rapid expansion of Azolla on the water surface, and a subsequent reduction in dissolved oxygen (hypoxia), which causes aquatic life mortality.
- **System Dynamics Modeling:** The systemic tools used to construct the conceptual models included Causal Loop Diagrams, based on the principles of System thinking and System Dynamics, and were developed in Vensim software.
- **Steps for Conceptual Model Construction:** Holding collaborative workshops with relevant experts. Mapping subsystems and defining variables. Integrating the subsystems to form an integrated conceptual model of the wetland ecosystem.
- **Overall Structure of the Watershed Model**

1.Socio-economic Subsystem: Includes variables related to population, agriculture, and industry.
2.Wetland Subsystem: Comprising four components:
Hydrology: The quantity and volume of water in the Anzali Wetland
Biology: The introduction of invasive species into the wetland.
Water Quality: Pollution and the phenomenon of eutrophication.
Morphology: Sedimentation

Results

- ✓ One positive reinforcing feedback loop was identified in the agricultural subsystem(Figure3), and two reinforcing feedback loops were found in the hydrological subsystem(Figure4).
- ✓ The conceptual model included 48 variables (12 of which were connecting variables) linked by 98 arrows.

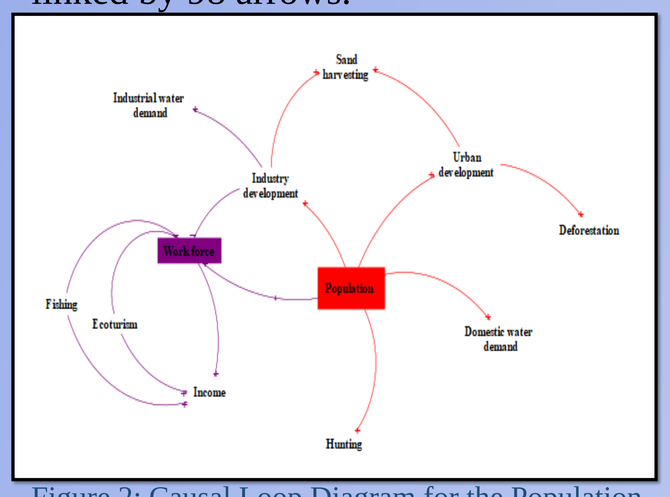

Figure 2: Causal Loop Diagram for the Population Subsystem

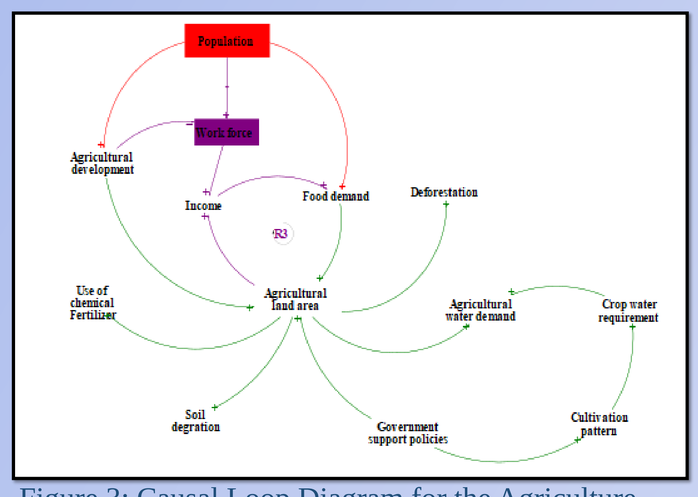

Figure 3: Causal Loop Diagram for the Agriculture Subsystem

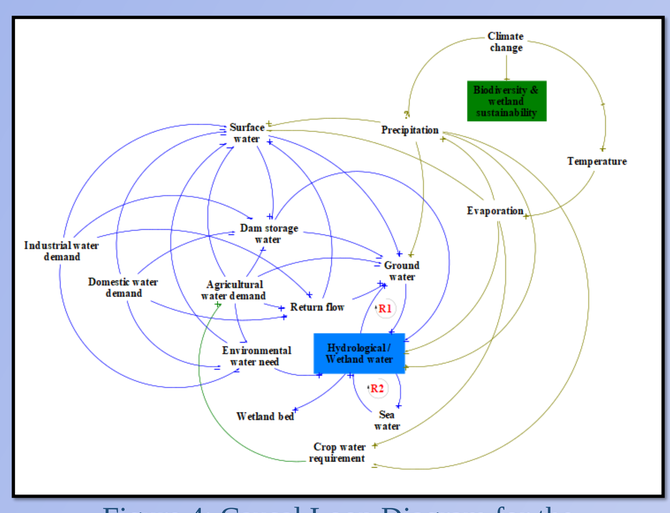

Figure 4: Causal Loop Diagram for the Hydrology Subsystem

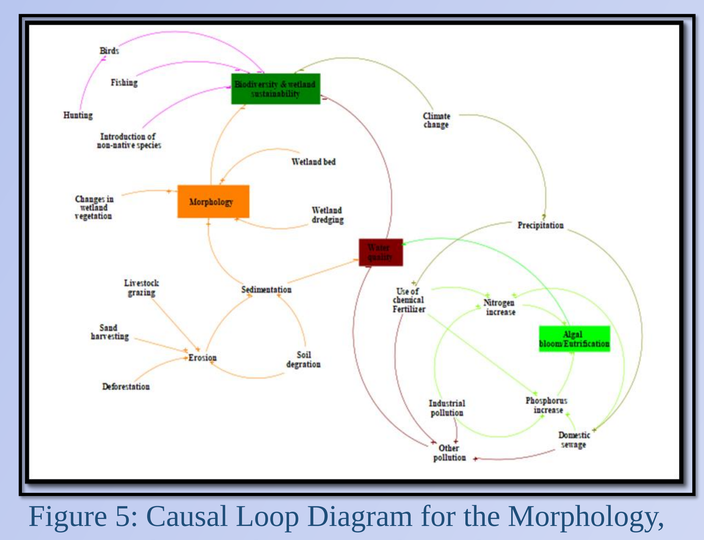

Figure 5: Causal Loop Diagram for the Morphology, Biology, and Water Quality Subsystems

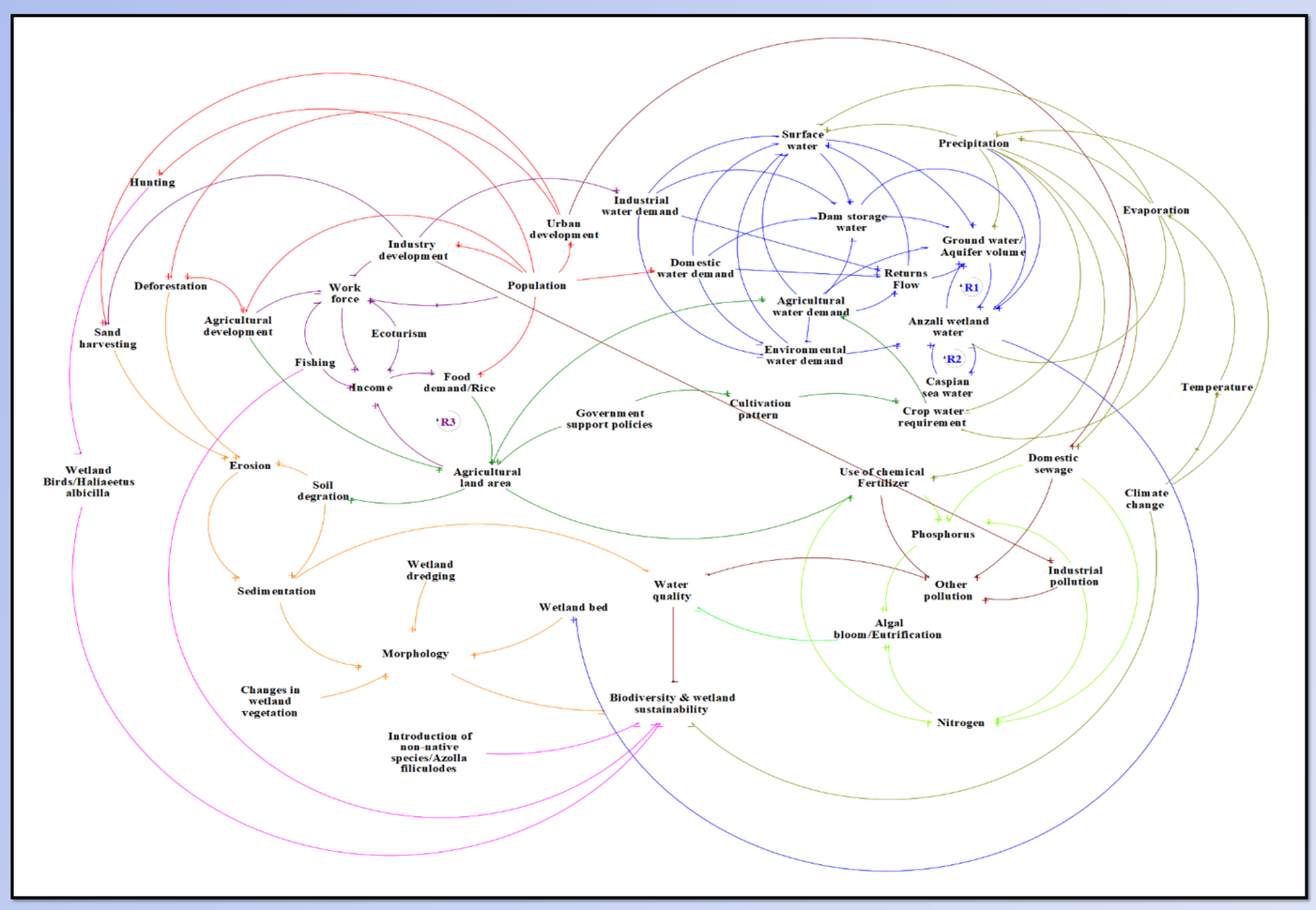

Figure 6: Integrated Conceptual Model of the Anzali Wetland

Conclusion

The watershed dynamics are influenced by various factors such as groundwater resources, the regression of the Caspian Sea, population growth, expansion of agricultural lands, climate change, food demand (especially for rice), and income. Within the conceptual model, factors like climate change, overfishing and hunting, invasive species, sedimentation, water depth (volume), dredging, pollution, and eutrophication were also identified as direct drivers of biodiversity and wetland sustainability. The three identified positive reinforcing loops constitute the leverage points of the conceptual model, and conservation management strategies should be designed and implemented in alignment with them. The integrated conceptual model provides a comprehensive and appropriate perspective for decision-makers.