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SUSTAINABLE RIVER ENGINEERING

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Abstract: Sustainable River engineering is an innovative approach that integrates engineering practices with ecological, social, and economic considerations to manage and restore river systems. Unlike traditional methods, which often prioritize infrastructure and short-term solutions, sustainable river engineering emphasizes resilience, biodiversity, and the preservation of natural processes. This approach involves using eco-friendly materials, restoring natural hydrological patterns, and implementing adaptive management strategies to address challenges such as flooding, erosion, habitat loss, and water quality degradation. By balancing human needs with environmental sustainability, sustainable river engineering promotes long-term benefits, including enhanced ecosystem health, improved water management, and reduced vulnerability to climate change. This abstract explores the principles, materials, and applications of sustainable river engineering, highlighting its potential to foster harmony between human activities and the natural environment.

Keywords: Sustainable River engineering, Ecological integration, social considerations, Economic considerations, River system management, Resilience, Biodiversity, Natural processes, Eco-friendly materials.

I. Introduction

Sustainable river engineering is an approach that focuses on the design, construction, and management of river systems in a way that balances ecological health, social needs, and economic development. The goal is to create river systems that are resilient, maintain biodiversity, and provide essential services to communities while minimizing negative impacts on the environment. This field integrates various disciplines, including hydrology, ecology, engineering, and social sciences, to address challenges such as flooding, habitat degradation, water quality, and the impacts of climate change. Sustainable river engineering practices may include the restoration of natural riverbanks, the implementation of green infrastructure.

Importance of Sustainable River Engineering

Sustainable river engineering is a critical field that aims to manage rivers and their surrounding ecosystems in ways that support both human activities and ecological health, without compromising the ability of future generations to meet their needs. The need for sustainable river engineering arises from the increasing pressures that rivers face due to urbanization, industrialization, agriculture, and climate change. Below are key reasons why sustainable river engineering is essential:

1. Environmental Protection

- **Ecosystem Health**: Rivers support diverse ecosystems, providing habitats for many species of fish, plants, and other wildlife. Unsustainable practices like damming, excessive water extraction, and pollution can severely damage these ecosystems. Sustainable river engineering seeks to protect these natural habitats, ensuring that biodiversity is maintained.
- **Water Quality**: Sustainable practices help in maintaining water quality by reducing contamination from industrial, agricultural, and urban runoff. Techniques like green infrastructure and natural filtration systems can help maintain clean and healthy water in rivers.

2. Energy Production

- **Hydropower with a Green Approach**: Hydropower is a significant source of renewable energy, but large-scale dams can disrupt ecosystems. Sustainable river engineering emphasizes small-scale, run-of-river hydropower projects that generate energy without significant environmental disruption.
- **Sediment Management**: Maintaining sediment transport is essential for the long-term health of river channels and adjacent landscapes. Sustainable river engineering practices balance energy production with the preservation of natural river dynamics, including sediment transport and deposition.

3. Flood Risk Management

- **Resilience to Climate Change**: Climate change has increased the frequency and intensity of extreme weather events, including floods and droughts. Sustainable river management incorporates climate resilience strategies that help rivers adapt to these changing conditions and reduce flood risks in vulnerable areas.
- **Flood Control**: River systems are dynamic, and flood events can cause widespread destruction. Sustainable river engineering uses natural floodplain management, levees, wetlands, and other green infrastructure techniques that help to mitigate flood risks while maintaining natural river dynamics.

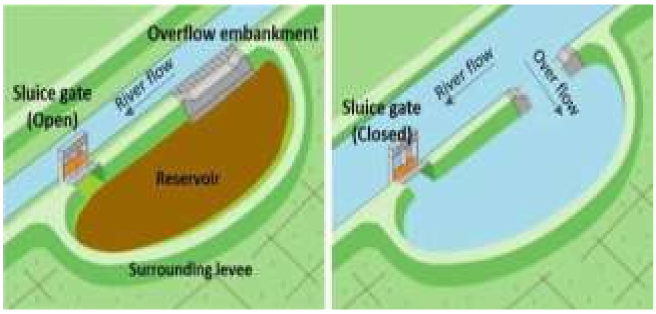

Figure 1: Flood control

4. **Recreation and Aesthetic Value**

- **Tourism**: Many rivers attract tourists for activities such as boating, fishing, hiking, and wildlife watching. Sustainable river engineering enhances the attractiveness of rivers by ensuring they remain healthy and accessible for recreational purposes.
- **Cultural Significance**: Rivers have deep cultural and historical importance to many communities. Sustainable management helps preserve these cultural values while accommodating development needs.

5. Supporting Human Communities

- **Water Supply**: Rivers are essential sources of drinking water and irrigation for agriculture. Sustainable management ensures that rivers provide clean, safe water without overexploiting the resources, which can lead to depletion or contamination of water supplies.
- **Agricultural Sustainability**: Rivers are critical for irrigation in many regions. Sustainable river engineering supports agriculture by ensuring that river flows are maintained at levels that meet both human and ecological needs. It also minimizes soil erosion and sedimentation caused by poor river management practices.
- **Erosion Control**: Unsustainable River engineering can cause soil erosion and the loss of land, particularly in floodplains. Sustainable techniques focus on controlling riverbank erosion through the use of vegetation and other natural systems, thereby protecting valuable land and infrastructure.

6. Climate Adaptation

- **Carbon Sequestration**: Healthy river ecosystems, such as wetlands and riparian forests, play a significant role in sequestering carbon and reducing the impacts of climate change. Sustainable river management helps preserve these carbon sinks, contributing to global efforts to mitigate climate change.
- **Water Cycle Regulation**: Rivers and their associated ecosystems regulate local and regional water cycles, ensuring balanced rainfall and groundwater recharge. Sustainable engineering practices help preserve these critical functions, reducing the risk of droughts and ensuring water availability during dry periods.

7. Long-Term Economic Viability

- **Cost-Effective Solutions**: While large-scale infrastructure projects might provide short-term benefits, they can be costly and difficult to maintain. Sustainable river engineering promotes solutions that offer long-term economic benefits by integrating natural processes and reducing the need for expensive infrastructure repairs and maintenance.
- **Investment in Natural Capital**: By preserving ecosystems and natural services like water filtration, flood regulation, and soil fertility, sustainable river engineering ensures that the economic benefits derived from rivers are maintained for future generations.

II. Sustainable River: Technologies and Functionality

Sustainable river engineering integrates advanced technologies and principles that preserve, restore, and enhance the ecological, social, and economic functions of river systems. The goal is to manage rivers in ways that meet the needs of current generations without compromising the ability of future generations to benefit from the same resources. Technologies in sustainable river engineering focus on working with natural processes, improving flood management, protecting water quality, and ensuring long-term river health. Below, we explore key technologies and their functionalities in sustainable river engineering.

1. **Natural Infrastructure and Ecosystem-Based Approaches**

- **Riparian Buffer Zones**:
  - **Functionality**: Vegetated riparian zones along riverbanks help stabilize soil, reduce erosion, filter pollutants, and provide habitats for wildlife. These zones act as natural barriers to buffer rivers from agricultural runoff, urban development, and other contaminants.
  - **Technology**: Land management technologies and GIS (Geographical Information Systems) tools are used to design and monitor these zones for optimal ecological benefits.

- **Floodplain Restoration**:
  - **Functionality**: Restoring natural floodplains allows rivers to overflow in controlled ways during high-water events, reducing the need for costly flood control infrastructure like levees. Floodplains also store water, filter pollutants, and provide habitats for wildlife.
  - **Technology**: Remote sensing and hydrological modeling technologies are used to assess floodplain restoration potential, simulating flood events to identify areas for effective restoration.
- **Wetland Restoration**:
  - **Functionality**: Wetlands are critical for water filtration, flood attenuation, and carbon sequestration. They also enhance biodiversity and can reduce the impacts of extreme weather events by absorbing floodwaters and maintaining groundwater levels.
  - **Technology**: Techniques like soil mapping, water quality monitoring, and hydrodynamic modeling help in restoring wetlands, assessing hydrological functions, and ensuring long-term sustainability.

2. Hydrological Modeling and Decision Support Systems

- **Hydrological and Hydraulic Modeling**:
  - **Functionality**: These models simulate river flow, sediment transport, and flood dynamics, allowing engineers to predict the impacts of various management strategies. This helps in designing sustainable interventions for flood protection, water quality, and sediment management.
  - **Technology**: Tools like HEC-RAS (Hydrologic Engineering Center's River Analysis System), MIKE 21, and SWMM (Storm Water Management Model) simulate river hydraulics, flooding scenarios, and watershed behavior, allowing engineers to test different solutions before implementation.
- **Integrated Decision Support Systems (IDSS)**:
  - **Functionality**: IDSS combines environmental, social, and economic data to support decision-making in river management. It helps integrate the priorities of different stakeholders—such as local communities, industries, and environmental agencies—into a comprehensive river management plan.
  - **Technology**: IDSS platforms often use GIS, cloud-based computing, and big data analytics to manage and analyze large datasets, offering real-time solutions for flood forecasting, water quality monitoring, and climate change adaptation.

3. Sustainable Water Management Technologies

- **Low-Impact Development (LID) Practices**:
  - **Functionality**: LID practices aim to mimic natural hydrological processes and reduce the impact of urbanization on rivers. These include techniques like green roofs, permeable pavements, and rain gardens that manage stormwater close to its source and promote groundwater recharge.
  - **Technology**: Computational fluid dynamics (CFD) and LID design software help engineers plan and implement LID systems effectively in urban watersheds to reduce runoff and improve water quality.
- **Water Harvesting and Reuse**:
  - **Functionality**: Water harvesting technologies capture excess river water or stormwater for irrigation, industrial use, or even potable water. This helps reduce pressure on river systems and encourages more sustainable water use.
  - **Technology**: Rainwater harvesting systems, desalination, and advanced filtration technologies are increasingly used in water-scarce regions, along with smart water management systems for efficient distribution and use.

4. River Restoration and Sediment Management

- **Streamflow and Sediment Transport Management**:
  - **Functionality**: River systems naturally transport sediments, but human activities such as dam construction and channelization disrupt these processes, leading to erosion and sedimentation problems. Sediment management technologies restore the natural flow of sediments, improving riverbed structure and supporting aquatic ecosystems.
  - **Technology**: Sediment transport models and sediment trapping technologies like sediment bypass systems, sediment dredging, and sedimentation basins are used to manage sediment loads in rivers and restore ecological balance.
- **Fish Passage and Aquatic Habitat Restoration**:
  - **Functionality**: Dams and other barriers often block fish migration. Fish passage technologies, such as fish ladders or fish-friendly turbines, restore migratory

pathways for species like salmon and eels, helping maintain biodiversity.
    - **Technology**: Sensor-based fish monitoring systems, like acoustic telemetry, and fish-friendly engineering designs such as fish passes, allow engineers to create more sustainable infrastructure that supports both human use and wildlife.

5. **Green Energy and Hydropower Alternatives**

- **Small-Scale Hydropower (Run-of-River Systems)**:
    - **Functionality**: Small-scale hydropower systems harness the natural flow of rivers without requiring large dams. These systems generate renewable energy while minimizing environmental disruption. Run-of-river plants, which divert water through turbines without impeding flow, offer a more sustainable alternative to traditional large-scale hydropower.
    - **Technology**: Micro-hydropower turbines and low-head hydropower systems are designed to optimize energy generation with minimal impact on river ecosystems.
- **Hydropower with Sediment Bypass Technology**:
    - **Functionality**: Dams often trap sediments, leading to downstream erosion and loss of fertile land. Sediment bypass systems enable sediments to pass through dams, restoring natural river dynamics and preventing sediment buildup.
    - **Technology**: Automated sediment management systems, such as sluicing or siphoning, ensure that sediment transport remains functional even in regulated river systems, allowing hydropower plants to operate sustainably.

6. **Smart Monitoring and Data Collection**

- **Remote Sensing and Satellite Technology**:
    - **Functionality**: Remote sensing technologies (satellites, drones, and ground-based sensors) provide valuable data on water quality, river morphology, flood levels, and environmental changes. This data can inform decision-making, monitor the success of restoration projects, and detect pollution or other harmful changes in river systems.
    - **Technology**: Satellite imaging (e.g., Landsat, Copernicus) and drones equipped with multispectral sensors provide real-time monitoring capabilities for river health assessment and management.
- **Environmental Monitoring Networks**:
    - **Functionality**: Sensor networks deployed in rivers can continuously monitor key indicators like water quality, flow rates, temperature, and pollution levels. These systems enable early detection of issues such as contamination or flow disruptions, allowing for timely responses.
    - **Technology**: Internet of Things (IoT) sensors, remote telemetry, and real-time data analytics platforms enable continuous environmental monitoring and data-driven decision-making.

III. Sustainable River Engineering Materials

Sustainable river engineering relies not only on **technological innovations** but also on the use of **eco-friendly materials** that minimize environmental impact, enhance the resilience of river systems, and contribute to long-term ecological stability. These materials are designed to align with the principles of sustainability, ensuring that interventions in river environments maintain or improve water quality, biodiversity, and ecosystem functions.

1) **Natural and Bio-Based Materials**

a) Vegetative Materials (Bioengineering Materials)

- **Functionality**:
    - Used for **erosion control**, **riverbank stabilization**, and **habitat restoration**.
    - Enhance **biodiversity** by providing natural habitats and food sources for aquatic and terrestrial species.
    - **Bioengineering materials** like plants, grasses, and shrubs help reduce the need for concrete and other synthetic materials, promoting ecosystem services like water filtration and soil stabilization.
- **Examples**:
    - **Willows**, **reed plants**, **coconut coir**, and **native grasses** for erosion control and riverbank reinforcement.
    - **Live staking** (planting live branches into soil to create a natural barrier).
    - **Geotextiles** (natural fabrics made from jute or coir used to protect riverbanks from erosion).
- **Benefits**:
    - Improve soil quality, **carbon sequestration**, and reduce stormwater runoff.
    - **Low carbon footprint** compared to concrete, steel, or other industrial materials.

b) Coconut Coir and Natural Fiber Matting

- **Functionality**:

- **Coconut coir** (the fibrous husk of coconuts) is used for **bank stabilization**, **erosion control**, and **sediment trapping**.
- Provides a **natural alternative** to synthetic geotextiles or concrete blocks.

- **Examples**:
  - **Coir geotextiles**, **coir logs**, and **coir mesh** for preventing soil erosion and promoting vegetation growth along riverbanks.
- **Benefits**:
  - Biodegradable, so they blend into the environment over time, reducing long-term waste.
  - Improves water quality by filtering pollutants and sediments.

2) **Sustainable Concrete Alternatives**

a) Geopolymer Concrete

- **Functionality**:
  - **Geopolymer concrete** is a more environmentally friendly alternative to traditional Portland cement. It is made using industrial byproducts like fly ash, slag, or metakaolin, reducing the carbon footprint of river infrastructure.
  - Used for **water-retaining structures** such as **riverbed reinforcement**, **erosion control**, and **bridge supports**.
- **Benefits**:
  - Significant reduction in **carbon emissions** compared to conventional concrete.
  - **Durability**: More resistant to corrosion and weathering, making it suitable for river and coastal environments.
- **Examples**:
  - Geopolymer-based **riverbank protection** walls or **weirs** that reduce erosion without harming the surrounding ecosystem.

b) Recycled Concrete Aggregate (RCA)

- **Functionality**:
  - Made from recycled construction materials, **RCA** is used as a sustainable option for river engineering structures like embankments and flood defenses.
  - Reduces the need for new raw materials, conserving natural resources and reducing the waste going to landfills.
- **Benefits**:
  - **Eco-friendly** alternative that reuses waste materials.
  - **Cost-effective**, as it is typically less expensive than new aggregate.
- **Examples**:
  - **Recycled concrete** used for constructing river embankments, **riprap**, and flood protection structures.

3) **3. Green Infrastructure Materials**

a) Permeable Pavement and Surfaces

- **Functionality**:
  - **Permeable pavements** allow water to flow through the surface, promoting natural infiltration into the ground and reducing runoff into rivers.
  - Often used in urban areas or near **stormwater outflows** to manage runoff before it reaches the river.
- **Benefits**:
  - **Reduces stormwater runoff** and **water pollution** by allowing rainwater to infiltrate the soil, preventing pollutants from entering the river.
  - Can help **recharge groundwater** and reduce the pressure on river systems.
- **Examples**:
  - **Porous asphalt**, **gravel pavers**, and **permeable concrete** used in parking lots, walkways, and urban drainage systems.

b) Green Roofs

- **Functionality**:
  - **Green roofs** (roofs covered with vegetation) capture and store rainwater, reducing runoff into rivers and helping to regulate urban temperatures.
  - The vegetation on green roofs can absorb pollutants from the air and provide insulation, reducing energy consumption in buildings.
- **Benefits**:
  - **Flood mitigation** by reducing stormwater runoff.
  - Enhances **biodiversity** by providing urban green spaces.
  - Improves water quality by filtering pollutants before they reach rivers.
- **Examples**:
  - **Vegetated roofs** on buildings in urban areas along river systems to manage runoff.

4) **4. Sustainable Erosion Control Materials**

a) Soil Stabilizers and Natural Polymers

- **Functionality**:
  - These materials help stabilize soils in riverbanks and streambeds, preventing

erosion without the need for synthetic chemicals.
  - Used in **riverbed restoration**, **floodplain management**, and **bank reinforcement**.
- **Examples**:
  - **Natural gums** and **biodegradable polymers** like **guar gum** or **xanthan gum** are used to bind soil particles and prevent erosion in sensitive areas.
- **Benefits**:
  - **Eco-friendly** and biodegradable, unlike synthetic stabilizers.
  - Provide effective **long-term erosion control** without harming ecosystems.

5) **Advanced Composite Materials**

a) Fiber-Reinforced Polymers (FRPs)

- **Functionality**:
  - **FRPs** are lightweight, durable, and resistant to corrosion, making them ideal for **river infrastructure** like **bridges**, **culverts**, and **hydropower plants**.
  - Used in places where corrosion from water or environmental factors is a concern.
- **Benefits**:
  - **Durability**: High resistance to corrosion from water and chemicals, reducing maintenance costs.
  - **Sustainability**: Can be made from recycled materials and are **100% recyclable** at the end of their lifespan.
- **Examples**:
  - **FRP sheets** for use in river-based infrastructures such as **protective barriers** or **water diversion structures**.

6) **Sustainable Materials for Flood Control**

a) Natural Stone and Riprap

- **Functionality**:
  - **Riprap** (large stones) is used for **bank stabilization**, **erosion control**, and **flood defense**. Natural stones help dissipate the energy of flowing water and protect riverbanks.
- **Benefits**:
  - **Locally sourced**, reducing transportation emissions.
  - Highly **durable** and effective in withstanding powerful river currents.
- **Examples**:
  - **Stone gabions** or **stone riprap** placed along riverbanks or around infrastructure like bridges to prevent erosion and provide structural support.

7) **Biodegradable Materials**

a) Biodegradable Geotextiles

- **Functionality**:
  - **Biodegradable geotextiles** are used for **riverbank stabilization** and **erosion control** in sensitive or ecologically important areas. Unlike synthetic geotextiles, these materials decompose naturally, reducing long-term waste.
- **Examples**:
  - **Jute mats**, **hemp geotextiles**, and other natural fiber materials that stabilize the soil and prevent erosion while allowing vegetation to grow.
- **Benefits**:
  - **Eco-friendly** and sustainable, leaving no long-term environmental impact after use.
  - Supports natural **habitat restoration** by allowing plant growth.

IV. Case Studies of Sustainable River Engineering

This section provides real-world examples of buildings that have successfully integrated and sustainable River Engineering.

Case Study 1: The Kissimmee River Restoration Project, Florida, USA

Key Features: Restored 40 square miles of wetlands by reconnecting the river's historic meandering channel. Increased biodiversity, improved water quality, and reduced flood risks. Highlighted the value of combining natural processes with engineered interventions for ecological recovery.

Outcome: A 92% increase in bird populations and the recovery of aquatic species, making it a global model for sustainable river restoration.

Figure 2: Kissimmee River

2. Case Study 2: Rhine River Restoration, Europe

Key Features: The Rhine River spans several European countries and has been heavily modified for navigation and flood control. Projects such as the "Integrated Rhine Program" reconnected floodplains, restored habitats, and improved water retention capacity.

Outcome: Recovered over 100 species of fish, including the salmon population. Reduced flood risks and improved ecological connectivity across the river basin.

Figure 3: Rhine River Restoration

3. **Case Study 3: yangtze river ecological restoration, China**

Key Features: Severe industrial pollution and habitat destruction necessitated large-scale restoration efforts. Programs focused on wetland restoration, water quality improvement, and banning harmful activities like sand mining.

Outcome: Protected aquatic life such as the Chinese sturgeon and the Yangtze finless porpoise. Enhanced the livelihoods of local communities through ecotourism and sustainable fishing practices.

Figure 4: yangtze river ecological restoration

V. Future Trends and Research Directions

- Sustainable river engineering is a promising field, but its implementation faces numerous challenges. Addressing these obstacles is essential for ensuring the long-term success of river restoration and management projects.
- Additionally, future directions must focus on advancing technologies, fostering collaboration, and integrating sustainability into broader water resource management frameworks.

VI. Conclusion

Sustainable river engineering represents a vital shift in how we approach the management and restoration of river systems. By integrating ecological principles, engineering practices, and community involvement, this approach addresses critical issues such as habitat loss, pollution, erosion, and climate change impacts. It emphasizes working with natural processes rather than against them, ensuring long-term environmental, economic, and social benefits. Although challenges such as conflicting stakeholder interests, resource limitations, and urbanization remain, the progress demonstrated through successful case studies around the world proves that sustainable solutions are achievable. Future efforts must focus on advancing technology, fostering interdisciplinary collaboration, and strengthening policies to ensure that sustainable river engineering becomes a standard practice.

VII. Acknowledgement

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VIII. References

The references should be formatted according to IEEE citation standards. Below is an example of how you might format your references:

1. Barrow, C. J. (1998) River basin development planning and management : A critical review. World Developemnt, v. 26(1), pp. 171–186.
2. Basu, B. and Srinivas, V. V (2013) Regional flood frequency analysis using Entropy-Based Clustering Approach. J. Hydrologic Engg., v. 21(8), pp. 1–12. doi: 10.1061/(ASCE)HE.1943-5584.0001351.
3. Booker, J. F., Michelsen, A. M. and Ward, F. A. (2005) Economic impact of alternative policy responses to prolonged and severe drought in the Rio Grande Basin.Water Resource Research, v. 41, pp. 1-16. doi: 10.1029/2004WR003486.
4. Braat, L. C. and Lierop, W.F.J. (1987) Integrated economic-ecological modelling, In: L.C. Braat, and W.E.J. Liero, (eds.), Integrated Economic Ecological Modeling,North Holland. Studies in Regional Science and Urban Economics, v. 16, pp. 49-67.
5. Cai, X., Mckinney, D. C. and Lasdon, L. S. (2002) A framework for sustainability analysis in water resources management and application to

the Syr Darya Basin. Water Resource Research, v. 38(6), pp. 21-1-21-14.

6. Cai, X., Mckinney, D. C. and Lasdon, L. S. (2003) Integrated hydrologic-agronomic-economic model for river basin management. Journal of Water Resources Planning and Management, v. 129(1), pp. 4–17.
7. Cai, X., Ringler, C. and Rosegrant M. W. (2006) Modeling water resources management at the basin level: Methodology and application to the Maipo River Basin. Research Report, 149. International Flood Policy Research Institute, Washington, DC.
8. Chitale, M.A. (1992) Development of India's river basins. International Journal of Water Resources Development, v. 8(1), pp 30-44.
9. Farolfi, S., Müller, J. and Bonté, B. (2010) An iterative construction of multi-agent models to represent water supply and demand dynamics at the catchment level. Environmental Modelling & Software, v. 25(10), pp. 1130-1148. doi: 10.1016/j.envsoft.2010.03.018.
10. Girard, C., Rinaudo, J., Pulido-Velazquez, M. and Caballero, Y. (2015) An interdisciplinary modelling framework for selecting adaptation measures at the river basin scale in a global change scenario. Environmental Modelling and Software, v. 69, pp. 42–54. doi: 10.1016/j.envsoft.2015.02.023.
11. Gumma, M. K., Thenkabail, P. and Nelson, A. (2011) Mapping irrigated areas using MODIS 250 meter time-series data: a study on Krishna River Baisn (India). Water, v. 3, pp. 113-131. doi: 10.3390/w3010113.
12. Guowei, L.I.U. (2001) Hydrology in ancient time in China. Paper presented to the International Symposium OH2 ' Origins and Histroy of Hydrology', Dijon, May 9-11, 2001.
13. Ministry of Water Resources, River Development & Ganga Rejuvenation (2017) Integrated Hydrological Data Book (Non-Classified River Basins), New Delhi, India.
14. Jena, P. P., Chatterjee, C., Pradhan G. and Mishra, A. (2014) Are recent frequent high floods in Mahanadi basin in eastern India due to increase in extreme rainfalls? Journal of Hydrology, v. 517, pp. 847–862. doi: 10.1016/j.jhydrol.2014.06.021.
15. Jenkins, M. W., Lund, J. R., Howitt, R. E., Draper, A. J., Msangi, S. M., Tanaka, S. K., Ritzema R. S. and Marques, G. F. (2004) Optimization of California’s water upply system : Results and insights. Journal of Water Resources Planning and Management, v.130(4), pp. 271–280.
16. Kotir, J. H., Smith, C., Brown, G., Marshall, N. and Johnstone, R. (2016) Science of the total environment: A system dynamics simulation model for sustainable water resources management and agricultural development in the Volta River Basin, Ghana. Science of the Total Environment, v. 573, pp. 444–457. doi: 10.1016/j.scitotenv.2016.08.081.
17. Kotir, J. H., Brown, G., Marshall, N. and Johnstone, R. (2017) Systemic feedback modelling for sustainable water resources management and agricultural development : An application of participatory modelling approach in the Volta River Basin. Environmental Modelling and Software. Elsevier Ltd, v. 88, pp. 106–118. doi: 10.1016/j.envsoft.2016.11.015.