Role of Geospatial Technology in Research & Development

By

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Geospatial Technology

In the modern world, knowingly or unknowingly all are using Geospatial Science & Technology

Remote Sensing (RS) +
Global Positioning System (GPS) +
Geographical Information System (GIS)

Common man to Military
Remote Sensing

Aerial Remote Sensing / Aerial Photography / Photogrammetry

Aircrafts

Helicopters

Air Balloons

Drones

Satellites

Satellite Remote Sensing

Space crafts / Satellites
Aerial Remote Sensing

Aerial Photography

Vertical

Inclined / Oblique
(International Borders)
Fiducial Marks
Stereoscopes to get 3D from Aerial Photos
Soft Copy Photogrammetry

Digital Photogrammetry
3D from Computer Screen
RADAR

World War II
RADAR

MICRO WAVES

TRANSMITTER

RECEIVER

TOWER

COMPUTER

Enemy’s Aircraft

MISSILE
A drone survey refers to the use of a drone, or unmanned aerial vehicle (UAV).

To capture aerial data with sensors, such as RGB or multispectral cameras, and LIDAR payloads.

The ground is photographed several times from different angles, and each image is tagged with coordinates.
Unlike manned aircraft or satellite, (1) drones can fly at a much lower altitude, (2) making the generation of high-resolution, (3) high-accuracy in data, (4) much faster, (5) less expensive (6) independent of atmospheric conditions such as cloud cover. & Site Specific study
Photogrammetry combines images that contain the same point on the ground from multiple vantage points to yield detailed 2D and 3D maps.
Agricultural Field

Smart Forming Concept in Agriculture
Geophysical Mapping

Geo-scanning

Electromagnetic Sensors in Drones

Aeromagnetic Survey
Sub-Surface Imaging

LIDAR Mapping

Drones for Archeological Survey

GPR Integrated Drones
LIDAR Images

Digital Elevation Models (DEM)

Digital Terrain Modeling (DTM)

Digital Contouring

3D Models
Sea Floor Mapping

Bathymetry Survey

Geotectonic Mapping

(Submarine Earthquakes & Tsunamis)
Disaster Mitigation

Forest Fire

Earthquake Disaster Management

Tsunami Inundation

Flood Monitoring

USGS Tests New Drone Technology to Measure Floodwaters

Missouri River at Hermann, Missouri
March 27, 2019
Hydrographic Survey using Aquatic Drones

Water Sampling & Quality Monitoring

Aquatic Drones for Dam Siltation Monitoring

Waste Collection from Water Bodies
Mining Activities

Mine Excellence Drone Platform
Get Meaningful Business Outcomes from Your Drone Data...

Dump Yard Volume Computation

Mine Planning and Development

Blast Monitoring

Pre & Post Blast Analysis
Geotechnical Monitoring
Environmental Monitoring
Rock Fragmentation
Equipment Inspection
Failure Analysis
Stockpile Reconciliation

Underground Tunneling
23
Land surveying / Cartography

3D Point Cloud

Road Construction Planning

Landslide Monitoring
Landfill Volume Measurement

Urban planning

Coastal Zone Management

To rescue swimmers

Zoning map overlayed on an aerial map of a mixed urban and leisure area.
Goods Delivery

Drug Delivery
Passenger Drones
Spy Purpose

Military Drones

Pouring tear gas
Underwater / Submarine Drones
Satellite Remote Sensing

Platform – Spacecraft

Scanner / Sensor
Types based on Source

Passive Remote Sensing

Active Remote Sensing
Classification of Satellites

Based on Orbit

1. Polar Orbiting (Sun Synchronous)
   - Height: 700 Km
   - Satellites: IRS, LANDSAT, SPOT, IKONOS

2. Geo Stationary
   - Height: 36000 Km
   - Satellites: INSAT, GOES

Based on Purpose

- Earth Resources Satellites
- Tele Communication Satellites
- Meteorological Satellites

Navigational
- GPS

Spy Satellites
- IRS
- INSAT
- GOES

Classification of Satellites
- IRS
- LANDSAT
- SPOT
- IKONOS
- INSAT
- GOES
- GPS
Geostationary Satellites

INSAT–1D image
Super Cyclone 1999, Orissa
Near-polar orbits

Launch Vehicles

PSLV
GSLV
SSLV

Development of Intercontinental Missiles
Spatial Resolution

Spatial Resolution of Important Satellites

- Landsat
- IRS 1A & 1B
- SPOT
- IRS 1C & 1 D
- IKONOS
- QuickBird
- TES
Landsat TM (8 bit)

SPOT PAN (8 bit)

IRS 1C PAN (6 bit)

IKONOS (11 bit)
Digital Image Processing
Anna University
Viewed by
IKONOS
GPS

(Global Positioning System)

- They were designed to calculate where you are and show you where to go along with how to get there. They can also be used to track where one has been to form cartographic journals.

- GPS signals are used to calculate its position on earth using trilateration. With four or more satellites in view it can used to determine a 3D position using latitude, longitude and altitude.
Satellites are reference points for locations on earth.

The Global Positioning System

Measurements of code-phase arrival times from at least four satellites are used to estimate four quantities: position in three dimensions (X, Y, Z) and GPS time (T).
Navstar GPS

Launched in by U.S in 1973 & Fully Operational in 1995

GPS Nominal Constellation
24 Satellites in 6 Orbital Planes
4 Satellites in each Plane
20,200 km Altitudes, 55 Degree Inclination
7 visible satellites
GPS Communication and Control
Accuracy

GOOD GDOP

POOR GDOP
Differential GPS (DGPS)
Base & Rover
GPS of Other Countries

**Russia** launched **GLONASS** (Global Navigation Satellite) in 1995 & expanded to the global level in 2011. Leading mobile companies like Samsung and Sony Ericsson used positive features of GLONASS in their devices launched in 2011.

**Galileo** is a Global Navigation Satellite System (GNSS) that was built by the European Union (EU), in collaboration with the European Space Agency. The system is powered by more than 30 Medium Earth Orbit satellites that have been operational since 2014. Almost all of the satellites are now fully functional, making the system one of the most accurate on the planet.

**Japan** is another leading power with its own navigation system. Japan’s **QZSS** or Quasi-Zenith Satellite System

**China** aims to become one of the strongest militaries in the world and it is not possible until it is capable of dominating the skies and space. **BeiDou Navigation Satellite System** (BDS) from China is a regional coverage (Indo - Pacific)
INDIA – IRNSS (NavIC)

PROVIDES INDIA WITH ASSURED NAVIGATION SERVICE FOR VITAL CIVILIAN & MILITARY APPLICATIONS WITHOUT HAVING TO DEPEND ON ANOTHER COUNTRY; FIRST SATELLITE TO BE LAUNCHED ON JULY 1; REMAINING 6 BY 2015

IRNSS: INDIAN REGIONAL NAVIGATION SATELLITE SYSTEM

- **7 SATELLITES**
  - 3 GEOSTATIONARY
  - 4 GEOSYNCHRONOUS

- ORBIT ALTITUDE: 36,000 KM
- COST: ₹1,420 CRORES

- **STAR SENSOR**
- **PROPELLANT TANK**
- **SOLAR PANEL**
- **LIQUID APOGEE MOTOR**

Covers India and up to 1,500 km beyond its borders.

- 3 extremely accurate rubidium atomic clocks in each satellite
- **GPS receivers will not work; need special receivers (yet to be developed)**

IRNSS provides Standard Positioning Service

- Open to all users
- Accuracy better than 20 metres

- 4 satellites in geosynchronous orbit – in pairs, move in two inclined orbits – appear from ground to travel in figure ‘8’ – assist in accurate position determination
- 3 satellites in geostationary orbit – appear from ground to be at fixed positions in the sky
India as well as the region extending up to 1500 km from its boundary
Applications of GPS
Airborne Laser Terrain Mapping
Volume determination

Measuring Topography (10km*10km)
Topography with GPS

Excavation and Filling
Earth Work

GPS Sensors on Bucket and Stick
Automatic landing

REFERENCE STATIONS
GPS Guided Precision Bombing

GPS Guided Missiles
GPS Guided Tanks & Artillery Shells
Mountain climbing
Spatial & Non-spatial Vector & Raster
From Points to Surfaces

DEM / DTM

TIN
Chithar

Bird’s eye View
Today’s technologies
for fast, efficient data capture

- One point
  - TPS
  - GPS
  - DISTO™

- Millions of points
  - Laser Scanning
  - Point-cloud Management

- Image-based
  - Aircraft-based
  - Remote sensing
  - Photogrammetry
Total Station with GPS
High Definition Surveying

**LIDAR** (Light Interference Detection And Ranging)
HDS Applications

- Buildings
  - 3D models
  - 2D drawings
  - Full colour visualisation

- Plant
  - Intelligent 3D CAD
  - Clash detection
  - CloudWorx within applications

- Civil/Survey
  - Road and rail
  - Volume calculations
  - Tunnelling

- Forensics & Other
  - Crash investigation
  - Archaeology
  - Entertainment
Topographic survey
Raw Point Cloud (with vegetation)
Point cloud with digital image
Superimposed
No Vegetation, only ground points
After vegetation removal

Point Cloud Data of Runchu Dam Site

Digital Contours
Digital Image – Singareni Collieries
Point Cloud
Humayu`s Tomb Data From Scanner
Point Cloud Data with Shaded Effect
Point Cloud Image with CAD Overlay

(Bibi ka maqbara)

Built 2D Drawing
Digital Image – India Gate

Point Cloud Data

Built 2D Drawing
Bridge & Overpass Construction Monitoring
Accurate rebar tie-wire inspection
HDS Scan Tunneling

Cross Section through HDS

Comparison between Design & As Built
ITS

SMART ROADS

SMART GATEWAYS

SMART VEHICLES
1. Support for prevention of collisions with forward obstacles

2. Support for prevention of overshooting on curve

3. Support for prevention of lane departure

4. Support for prevention of crossing collisions

5. Support for prevention of right turn collisions

6. Support for prevention of collisions with pedestrians crossing streets

7. Support for road surface condition information for maintaining headway etc.
METEOROLOGICAL INFORMATION

- Wind Speed
- Air Temperature
- Humidity
- Visibility
- Road Temperature

ROUTE GUIDANCE

- Real Time Traffic Analysis
- Optimised Travel Paths
How Real-Time GPS Tracking Works

GPS Satellite

GPS Trackers

Cellular Network

Servers

Computer, Laptop or Mobile Device

Internet
FOR EMERGENCY SITUATION

Route Guidance for Emergency Vehicles and Support for Relief Activities
Automatic Emergency Notification

Emergency Control Center

Danger Warning

Slow down! Falling objects ahead

Falling objects ahead!
PEDESTRIAN GUIDANCE

Pedestrian Route Guidance

Vehicle-Pedestrian Accident Avoidance

Prolonging of walk signal duration
AUTOMATED VEHICLE

Automated Highway Systems
Disabled Vehicle – Drive Carefully

Road Closed due to Heavy Rainfall
Optimization of Traffic Flow

Signal Control

Information Provision

Recommended Route
Turn Left
Exploration

Geological & Mineral Exploration
Marine Exploration
Groundwater Exploration
Oil / Petroleum (Hydrocarbon) Exploration
Archaeological Studies
Geotechnical Investigation etc.,
Marine Exploration - Samudra Ratnakar Research Vessel (GSI)

Sagar Nidhi - NIOT
Map showing important sites of poly-metallic nodules in Indian Ocean (Source: NIOT)

**Nodules in Central Indian Ocean Basin**
Marine Fossils collected during exploration

Polymetallic Nodules

Seamount containing sulphide deposits

Cobalt rich crusts collected from Andaman Sea

Source: GSI
Bathymetry Survey

Single Beam Echo Sounder Surveys

Multibeam Full Bottom Coverage
Grab Sampler
Core Samples from Ocean Bottom
Sample Testing – Onboard Laboratory
Seismic Guns

Remotely Operated Vehicle (ROV)

Synthetic Aperture Sonar (SAS) Image
Technology is required for deep sea mining

Flexible Riser System

Underwater Mining Machine

SCUBA
Mapping of groundwater potential zones in Salem Chalk Hills, Tamil Nadu, India, using remote sensing and GIS techniques

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Abstract This study proposes to introduce the remote sensing and geographic information system (GIS) techniques in mapping the groundwater potential zones. Remote sensing and GIS techniques have been used to map the groundwater potential zones in Salem Chalk Hills, Tamil Nadu. Quality maps depicting the potential groundwater zone, and the thickness of the weathered and fracture zones were extracted using a GIS tool. The study area was divided into zones of different potential groundwater zones based on the output of the study. The results are compared with the existing groundwater potential zones in the study area. The results show that the thickness of the weathered and fracture zone varies from 2.2 to 50 m in gneissic formation and 5.8 to 55 m in charnockite. The contact of gneiss and charnockite, the thickness ranges from 9.0 to 90.8 m favoring good groundwater potential. The mine lease area is underlain by fractured and weathered horblende biotite gneiss where groundwater potential is good. Water catchment tanks in this area of 5 km radius are small to moderate in size and are only seasonal. They remain dry during summer seasons. As per the survey, the water resources are remote, the domestic and agricultural activities in this region depend mainly upon the groundwater resources. The mine is located in gently slope area, and accumulation of water is not observed except in mine pits even during the monsoon period. Therefore, it is essential to map the groundwater potential zones for proper management of the aquifer system. Satellite images were also used to extract lineaments, hydrogeologic landforms, drainage patterns, and land use, which are the major controlling factors for the occurrence of groundwater. Various thematic maps pertaining to groundwater existence such as geology, geomorphology, land use, and lineaments, linear density, drainage density, slope, and soil were generated using GIS tool. By integrating all the above thematic layers based on the ranks and weightages, eventually, groundwater potential zones were demarcated. The study indicates that groundwater potential is good to high in 22 villages and moderate in 13 villages. The good to high potential zone occupies an area of 128 km² and moderate potential zone occupies an area of 77 km². Groundwater occurrence is poor in five villages which need artificial recharge to augment groundwater.

Introduction Groundwater is generally perceived as a tried and true wellspring of water to meet the needs of household, agricultural and industrial sectors. However, irrigation and uncontrolled groundwater resource development and enhanced human activities such as mining, industry and agriculture have resulted in groundwater pollution, over-extraction and land quality degradation problems (Li et al. 2018a, b; Wu et al. 2015, 2019). He and Wu (2019a, He et al. 2019). Groundwater is of significance in India, as a result of the expanding populace and urbanization, for the most part in regions that have insufficient surface water supply plans. It is estimated that about half of the urban and over 85% of rural populace relies upon groundwater for their drinking purposes and around 60% of the aggregate water system in the nation relies upon the same. CGWB (2011) reports that out of the 57233 pieces of watershed surveyed in the nation, 879 are considered as completely misused, 226 as risky and 30 are tainted with saline groundwater.
Remote Sensing and GIS Tool to Detect Hydrocarbon Prospect in Nagapattinam Sub Basin, India

S. Prabaharan · M. Ramalingam · T. Subramani · C. Lakshmanan

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Abstract  Caucrury Basin is one of the pericratonic rift basins located in the east coast of Tamil Nadu. The rifting has resulted in a series of horst and grabens. The present study uses a new technique which was devised with the help of GIS by analyzing the surface lineaments and subsurface linearies effectively. In this present study, a satellite image based analysis was conducted for extracting surface lineaments, and for the subsurface linearities, the basement linearies were extracted from seismic, magnetic, and gravity data. An orientation analysis of these surface and subsurface linear features was performed to detect the basic structural grains of the study area. The correlation between these structural grains and subsurface oil and gas traps was performed to understand the connectivity to the reservoirs. The article discusses in detail about the same and the importance of geologic sand surface and subsurface lineament analyses for delineating hydrocarbon reservoirs in the Nagapattinam Sub-Basin of Caucrury Basin.

Keywords  Lineaments · Structural grains · IRS-P-6 · LISS-III · Caucrury Basin

1 Introduction

Caucrury Basin, formed during late Jurassic period by sagging of a part of the Indian shield mainly along the dominant NE-SW eastern ghat trend, is located in the southern part of east coast of India between the northerly plunging Sri Lanka basement masif and the peninsular craton (Subramanyam et al. 1995). It occupies an area of 25,000 sq km on land basin and 35,000 sq km offshore (Kumar 1983). Subsurface studies over onshore parts of the basin have revealed the basinal trend and the main NE-SW structural features, viz., Pondicherry, Tranquebar, and Nagapattinam depressions, separated by Kumbakonam–Shyall ridge, Kanyakumari high and Vedanayam high (Sastri et al. 1973; Kumar 1983; Venkatagiri 1987). Geomorphological and morphotectonic studies have been carried out by many earlier researchers based on air photos and landsat images (Varadarajan 1969; Varadarajan and Balakrishnan 1982; Mahajan et al. 1984; Mitra and Agarwal 1991). The surface linear features have been used to search for additional reserves in mature oil gas fields (Herman et al. 1986; Guo and Carroll 1995).

References


Blinkford HF (1865) Crescias and other rocks of the South Arcot and Trichinopoly districts. Memoir Geol Surv India 423–125


Herman J (1986) Remote sensing Study of the Mid-continent Geophysical Anomaly in Iowa. Paper presented at the society of mining engineering fall meeting, St. Louis, Missouri, September 7–10

Kumar SP (1983) Geology and hydrocarbon prospects of Krishnagiri and Caucrury basin. Pat Asia 557–65

Route Alignment (Location) using Geospatial Technology

Road way
Rail way
Underground Cables
Gas Pipe lines
Canal Alignment
Power lines
Drainage Network in Cities etc.,
Mitigation of environmental impacts due to ghat road formation in Palamalai Hills, South India, by optimizing cut and fill volumes using GPS and GIS techniques

R. Arulmozhi, T. Subramani & S. Sukumar

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Ghat road alignment in Palamalai Hills, Tamil Nadu, India using Ghat Tracer, GPS and GIS

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Present study was conducted while fixing alignment in the study area Palamalai hills from Mulakkadai village in the plains to Keemumpatti village on the top of the hill. In this work survey to form road from Mulakkadai to Keemumpatti was conducted using Ghat Tracer, Total Station and GPS. The elevation of the starting point of the road is 320 m and the hill top is 742 m above mean sea level (MSL). Road alignment in the hilly terrain was fixed using Ghat Tracer with a gradient of 6%. Length of the alignment in the ghat section is 6.30 km with eight hairpin bends. Total station and GPS surveys were conducted along the alignment to get the coordinates. Using the data alignment plans and longitudinal sections were prepared for the proposed road. A digital map was prepared for the study area by digitizing contours, drains, roads, forest boundaries and villages. From the elevation data a digital elevation model (DEM) was prepared using GIS software. GIS was further used for creating alignment plans with 6.00 m buffer to represent the road width. The implications of using these modern technologies in time and cost aspects were discussed in this work.

[Keywords: Road alignment in hilly terrain, Ghat trace survey, GPS and GIS in road alignment, Palamalai hill, South India]

Introduction
Planning of road alignment in hilly terrain is a difficult task when comparing it in plains. Several factors need to be evaluated to choose the best alignment among alternatives in hill roads1. Conventional methods are more time consuming and expensive for the extraction of surface profile information required for road alignment2. It is perceived that the use of Geographical Information System (GIS) in the task will reduce the difficulties of such work. Using maps alone to determine routes is tedious, time consuming and less accurate. On the other hand, a good model for road planning should incorporate the knowledge of the road engineer and be simple and easy to use4,6.

During the last decades, a few attempts were made to automate the route planning process using GIS technology. A review of a number of papers suggests that the planning of hill road using GIS will result in a safer and cost-effective route with lower construction and maintenance costs5.

The first step involved in hill road planning is tracing various tentative alignments on the ground. This is done by using the ghat tracer instrument or other suitable methods with designated gradient usually between 5% and 7%. The next step is to find the coordinate and elevations of the path at close intervals using compass and leveling instruments in the oden or the total station. Using this data, plan and profile of various tentative alignments are prepared and studied for their merits and the final one is selected based on safety and economy. Doing total station survey in adverse hilly terrain conditions along all the alternate alignments is tedious and time consuming. Therefore Global Positioning System (GPS) survey is used in the alternate alignments to get the plan and profiles to study them for their merits before selecting the final one. Accuracy of GPS data is sufficient for this purpose. The total station will be used only along the final alignment to take precise data for estimation and construction purposes.

Materials and Methods:
The study area Palamalai hill is geographically located within latitude 11° 38' 00" - 11° 52' 00" N and longitude 77° 42' 00" - 77° 48' 00" E and physically situated in Kolathur panchayat union of Salem district in the State of Tamil Nadu, South India on the banks of the river Cauvery. Proposed road formation is from Mulakkadai a village located on the existing road in the plains to Keemumpatti a remote unconnected village on the top (Fig 1). Palamalai is a isolated hill and its length is 22 km and width varies between 4 km and 5 km. The slope of the hill varies from 320 to 1450 m. According to revenue classification the area is under reserved
Basic Facilities not Available

Village on the Top (Kemmampatti)

Existing Footpath
DGPS with GIS
(Arc Pad for Mobile Mapping)

Bag-Back

Palmtop (Pocket PC)
Very much useful to the Society
Engineering Solution for the Problem

Implementation of Research Work by Government
Canal Alignment
WEIR Site Selection & CANAL Route Alignment

Water Resources Development

- Rain fed tanks
- Barren Land
Underground Utilities

Power line Network
Site Selection for Various Projects

Dam Site Selection

Weir / Reservoir / Bridge Site

Nuclear Reactor

Airport

Port / Harbour

Waste Disposal Site

Treatment Plants

Telecommunication (Mobile) Towers

Industrial Location

Sites for Groundwater Recharge etc.,
Waste Disposal Site Selection

Nearly 200 Citations

Impact of leachate on groundwater pollution due to non-engineered municipal solid waste landfill sites of erode city, Tamil Nadu, India

Rajkumar Nagarajan¹, Subramani Thirumalaisamy² and Elango Lakshmanan²

Abstract
Leachate and groundwater samples were collected from Vendipalayam, Semur and Vairapalayam landfill sites in Erode city, Tamil Nadu, India, to study the possible impact of leachate percolation on groundwater quality. Concentrations of various physicochemical parameters including heavy metals (Cd, Cr, Cu, Fe, Ni, Pb, Fe and Zn) were determined in leachate samples and are reported. The concentrations of Cl⁻, NO₃⁻, SO₄²⁻, NH₄⁺ were found to be in considerable levels in the groundwater samples particularly near to the landfill sites, likely indicating that groundwater quality is being significantly affected by leachate percolation. Further they were proved to be the tracers for groundwater contamination near Semur and Vendipalayam dumpyards. The presence of contaminants in groundwater particularly near the landfill sites warns its quality and thus renders the associated aquifer unreliable for domestic water supply and other uses. Although some remedial measures are suggested to reduce further groundwater contamination via leachate percolation, the present study demands for the proper management of waste in Erode city.

Keywords: Solid waste management, Groundwater contamination, Landfill, Leachate
Geospatial Technology in Cell Phone Tower Site Selection

Cell Tower Map
Cell Tower Coverage Map

Understanding Mobile Traffic Patterns
Groundwater chemistry and demarcation of seawater intrusion zones in the Thamirabarani delta of south India based on geochemical signatures

V. Satheeskumar · T. Subramani · C. Lakshumanan · Priyadarshi D. Roy · D. Karumanidhi

Abstract Sub-surface water samples from the delta of Thamirabarani River of south India were evaluated for human health risks and seawater intrusion using the geochemical signatures. Electrical conductivity (EC), total dissolved solids (TDS), pH and the concentrations of major cations and anions in 40 samples collected during the winter (January) and summer (July) of 2018 show comparable values. Subsequently, the results were verified with respect to the international drinking water quality standards. The Piper trilinear diagram shows mixed Ca–Mg–Cl, Na–Cl, Ca–HCO₃ and mixed Ca–Na–HCO₃ facies in the samples. Similarly, the plenteous of cations are sequenced as Na⁺ > Ca²⁺ > Mg²⁺ > K⁺ and the plenteous of anions are sequenced as Cl⁻ > SO₄²⁻ > HCO₃⁻ > Br⁻ > NO₃⁻ > PO₄³⁻. Gibbs plots illustrate that rock-water interaction and evaporation control the geochemistry of sub-surface water. More than 40% of the samples are unsuitable for drinking, and their higher EC and TDS values reflected the seawater contamination. The high values in the groundwater also indicate anthropogenic activities (salt panning). Interrelationship of ions of sub-surface water was used to get a better insight into the saline water intrusion in the study area. To mitigate the river water salinization and seawater incursion in the aquifers, engineering solution such as weir construction across the Thamirabarani River near Mukkani village has been proposed. After construction of the weir, freshwater in the river can be diverted to the salt-affected and seawater-interrupted areas to improve the scenario.

Keywords Geochemical signature · Drinking water quality · Seawater intrusion · Thamirabarani delta · South India

Introduction

The quality and quantity of freshwater are continuously declining due to the overexploitation of water resources for various anthropogenic necessities such as domestic, agricultural, and industrial needs. Consequently, river water salinization occurs in many of the coastal aquifers around the globe. The shape and degree of seawater intrusion in a coastal aquifer depend on several factors. Some of these are natural and cannot be controlled, while others are manmade and could, thus, be managed. Seawater intrusion is defined as a coastal area natural hazard harmful to human life and includes not only the direct hazard of disastrous seawater caused by storm tides, but also the hazard of intruded seawater penetrating into fresh water aquifers. Less than 2% of seawater intrusion in the fresh water can diminish the water availability.

The Thamirabarani delta, located between latitudes 8° 35′ N to 8° 45′ N and longitudes 78° 00′ E to 78° 10′ E in southern Tamil Nadu state, India, is one such important delta where the salinization of river water and groundwater are common. This region is further threatened by the increased salinity activities. Thus, a detailed study was carried out with the main objective of minimizing salinization of river water and groundwater.

Materials and Method:
The Brahmaputra River originates 1,500 m above sea level on a part of the Annamalai range on the eastern slopes of the Western Ghats in the Tirunelveli District of Tamil Nadu and flows through Tirunelveli and Tuticorin districts of the Tamil Nadu state of southern India.
Weir Site Selection

Pumping Station

Temporary Bunds
Deepening of River Channel

River

Earthen Bund

Sea Water

on
Salt Affected Agricultural land

Saltpan Activities Recent & Very Old

Salt Affected Agricultural land

Dense Saline Groundwater for Saltpan

Groundwater from Deeper Aquifer.
Engineering Solution

Plan & Sectional View of the Weir

HALF LONGITUDINAL SECTION ALONG C.L OF BODY WALL
AND HALF FRONT ELEVATION
Implementation of Research Work
(Very much useful to the Farmers & Industrial People)

Construction of Weir by TN Government
Geospatial Technology for Artificial Recharge of Groundwater

Promoting artificial recharge to enhance groundwater potential in the lower Bhavani River basin of South India using geospatial techniques

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Environ Sci Pollut Res
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Fig. 3 Existing artificial recharge structures in the lower Bhavani River basin and their physical conditions: a good, b semi-critical, c critical and d damaged

Year – 2020

IF = 4.223
Locations of the existing Recharge Structures

Integration of various themes for New site Selection

Fig. 4 Spatial distribution of existing artificial recharge structures: a check dams, b percolation ponds, c flood & furrows, d ditch & furrows, e induced recharge wells and f recharge pits and their physical conditions.
Rainfall-surface runoff estimation for the Lower Bhavani basin in south India using SCS-CN model and geospatial techniques

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Abstract
Rainfall and surface runoff are the two most important components, which control the groundwater recharge of the basin. The long-term groundwater recharge of an aquifer gets affected by the population growth, irregular agriculture activities and industrialisation. Hence, estimation of rainfall-surface runoff is very much essential for proper groundwater management practices. In the present study, Soil Conservation Service Curve Number (SCS-CN) model was employed in combination with geospatial techniques to estimate rainfall-surface runoff for the Lower Bhavani River basin in South India. To develop the SCS-CN model, rainfall data were obtained for 33 years (1983–2015) from 22 rain gauge stations spread over the basin. IRS LISS-IV satellite data of 5.8 m spatial resolution were used to analyze the land use/land cover (LULC) behavior. Based on the soil properties, four Hydrological Soil Groups (HSG) were identified in the basin which is most significant for surface runoff estimation. Curve Number (CN) values were obtained for various Antecedent Moisture Conditions (AMC) such as dry condition (AMC I), average condition (AMC II) and wet condition (AMC III). Spatial distribution of CN values was plotted using Geographical Information System (GIS) for the entire Lower Bhavani Basin to assess the surface runoff potential. The results indicate that the annual rainfall varies from 267 mm (2002) to 528.6 mm (2005), and the annual surface runoff varies from 102.04 mm (1985) to 463.02 mm (2010). The SCS-CN model outputs predict that the average surface runoff of the basin is 211.99 mm, and the average surface runoff volume is 81,995,380 m³. The study also indicates that nearly 53% of the basin area is dominated by high to very high surface runoff potential. Finally, the output of surface runoff potential was validated with the Average Groundwater Level Fluctuation (AGLF) observed in 57 wells spread over the entire basin. The basin AGLF ranges from 2.32 to 21.72 m. The surface runoff potential categories are satisfactorily matching with the AGLF categories. Moderate surface runoff as well as moderate AGLF zones mostly occupy the central portion of the basin, which possess good groundwater potential. However, the high surface runoff zones in the basin lead more surface water flow into the river channels, which reduce the irrigation rate and decline the water table. This problem can be solved by constructing suitable artificial groundwater recharge structures across the river channels in the high surface runoff potential areas.

Keywords: Rainfall-surface runoff, Geospatial techniques, SCS-CN, Runoff potential, Lower Bhavani basin, South India.
Disaster Mitigation

Landslide
Earthquake
Tsunami
Forest Fire
Volcanic Eruption
Cyclone & Flooding
Environmental Pollution
Covid – 19 etc.,
Demarcation of landslide vulnerable zones in and around Achanakal, South India using remote sensing and GIS techniques

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Present study attempted in Kattery watershed, Nilgiris District, Tamil Nadu, India where a major landslide occurred on 5th November 2008. Various thematic maps pertaining to landslide hazard studies were prepared from the top-sheets and satellite images using Geographical Information System (GIS). Landslide hazard zonation map of Kattery watershed was prepared by assigning proper weights and ranks for various themes. The north eastern and south-eastern part of Kattery watershed is more vulnerable to landslides and the south-western part is least vulnerable.

Introduction

A landslide is a geological phenomenon due to the movement of a mass of rock debris, or earth down the slopes and encompasses events such as ground movement, rock falls, and failures of slopes, topples, slides, spreads, and flows such as debris flows, mudflows or mudslides. It often takes place in conjunction with earthquakes, floods and volcanic eruption. In the hilly terrain of India including the Himalayas, landslides have been a major and widely spread natural disaster that often strike life and property. Slope instability is a geo-dynamic process that naturally shapes up the geomorphology of the earth. However they are a major concern when those unstable slopes would have an effect on the safety of people and property.

Landslides in Western Ghats (region like Nilgiris) which occur frequently, often result in significant damage to property and agriculture. The trigger for the landslides is a period of heavy rainfall, and as there had been little effort to assess or predict the events, damage was extensive. Kattery Watershed is in the Nilgiri hills of Western Ghats mountains system. It is situated at 6 km from Ooty on the Ooty-Combaatore Road, Tamil Nadu, India. It falls between latitudes 76°41'0"E ~ 76°45'0"E and longitudes 11°19'0"N ~ 11°24'0"N. The watershed comes in the Survey of India top-sheet 38 A/11 published on 1: 50,000 scale. The watershed has a maximum elevation of 2400 m above MSL and is characterised with steep slope, lateritic soils and fairly good drainage network. Forests, cultivation of potato and other vegetables on inwardly graded bench terraces was widely adopted earlier and thus problem of erosion and sedimentation down below were largely seen. However, about two decades before, with market fluctuations tea plantation has become popular.

Conclusion

Landslide hazard zonation mapping was attempted in and around Achanakal region, Ooty Hills, Tamil Nadu, India using remote sensing and GIS techniques. Initially various thematic maps...
Fluoride contamination in groundwater of the Shanmuganadhi River basin (south India) and its association with other chemical constituents using geographical information system and multivariate statistics

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Groundwater quality
Fluoride
Statistical analysis
Factor analysis
Shanmuganadhi River basin

ABSTRACT
Contamination of fluoride in drinking water affects human health, and its reduction is essential for the safe utilization of groundwater for domestic and agricultural uses. Groundwater in the ephemeral (monsoonal) Shanmuganadhi River basin, situated at rain shadow of the Western Ghats (south India), is indiscriminately utilized for rural water supply and agricultural activities. Fluoride contamination in groundwater of the river basin was evaluated using geochemical characteristics of sixty-one groundwater samples collected from the observation wells. Groundwater quality evaluation was attempted by estimating pH, Total Dissolved Solids (TDS), Electrical Conductivity (EC), and concentrations of Ca\textsuperscript{2+}, Mg\textsuperscript{2+}, Na\textsuperscript{+}, K\textsuperscript{+}, HCO\textsubscript{3}\textsuperscript{-}, Cl\textsuperscript{-}, SO\textsubscript{4}\textsuperscript{2-}, NO\textsubscript{3}\textsuperscript{-}, PO\textsubscript{4}\textsuperscript{3-} and F\textsuperscript{-}. Multivariate statistical techniques helped to identify the factors responsible for fluoride enrichment. The fluoride ion ranges from 0.01 to 2.5 mg/l with 77 % of the samples having less than 1.5 mg/l. Groundwater samples (23 %) with more than 1.5 mg/l of F\textsuperscript{-} are unsuitable for consumption. Fluoride vulnerable zones were mapped using the Geographical Information System (GIS) in which fourteen villages of the basin are with risk category for dental fluorosis among children. The multivariate statistical techniques (including correlation matrix) highlight the relationship among various geochemical parameters, and the cluster analysis apprehends the sources/processes contributing the chemical variables. Based on this study, it is recommended to adopt natural remediation technique like Managed Aquifer Recharge (MAR) for the enhancement of groundwater quality in this basin.
Spatial Representation is useful for Interpretation of Data

May be due to Fertilizers used for Agriculture (Red Colour)

Fig. 3. Spatial maps of groundwater quality parameters showing suitable areas for drinking purposes: a) EC, b) TDS, c) calcium, d) magnesium, e) sodium, f) potassium, g) bicarbonate, h) chloride, i) sulphate, j) phosphate, k) nitrate, and l) fluoride.
Perchlorate Contamination in Groundwater and Associated Health Risks from Fireworks Manufacturing Area (Sivakasi region) of South India

D. Karunanidhi¹ - P. Aravinthasamy¹ - T. Subramani² - H. A. H. Chandra Jayasena³

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Abstract
The principal goal of the current study is to assess perchlorate contamination of groundwater and related health risks from the fireworks manufacturing area (Sivakasi) in South India. Seventy-four groundwater samples were gathered and analysed for electrical conductivity (EC), pH, total dissolved solids (TDS), sodium (Na⁺), magnesium (Mg²⁺), calcium (Ca²⁺), potassium (K⁺), sulphate (SO₄²⁻), bicarbonate (HCO₃⁻), chloride (Cl⁻), fluoride (F⁻), nitrate (NO₃⁻), and perchlorate (ClO₄⁻). Perchlorate ranged from 0.00 to 0.21 mg/l with an average of 0.08 mg/l. About 61% of the samples (n = 45) contained higher perchlorate concentrations than the recommended level (0.07 mg/L) of World Health Organization (WHO). Similarly, 360.18 km² of area exceeds the permissible limit of perchlorate as per WHO. Correlation analysis indicates that groundwater contamination is mainly caused due to anthropogenic activities. Vertical distribution results indicate that 52% of the samples fall in the ‘high-risk’ category, 39% of the samples fall under the ‘very high-risk’ category and 9% of the samples fall under ‘safe’ category in the shallow aquifer of depth up to 15 m from the ground level. Total Hazard Index (THI) results reveal that about 70%, 60%, and 40% of the samples are more vulnerable (THI > 1) for infants, children, and adults. This study suggests that higher health risks inferred for infants must be cared with a suitable management plan to recover the quality of the water to evade major health problems in the future.

Keywords Groundwater · Perchlorate · Anthropogenic activities · Vertical distribution · Total hazard index · South India
Reason for High Perchlorate - More Fireworks

Spatial Variation Diagrams using GIS Software
Provincial and seasonal influences on heavy metals in the Noyyal River of South India and their human health hazards

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b Department of Geology, CEG, Anna University, Chennai, 600025, India
c Department of Geology, University of Peradeniya, Peradeniya, 20400, Sri Lanka
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e Institute of Earth Sciences, ICT, Pole of University of Minho, Campus de Gualtar, 4710- 057, Braga, Portugal

ABSTRACT

This study was carried out to evaluate the heavy metals (Lead (Pb), Nickel (Ni), Chromium (Cr), Copper (Cu), Cadmium (Cd) and Zinc (Zn)) pollution in the Noyyal River of South India by collecting 130 river water samples (65 each in pre- and post-monsoon). The heavy metals were measured using Atomic Absorption Spectrophotometer (AAS). The data were used to calculate the associated health hazards for the inhabitants consume river water. Correlation analyses and average concentration of heavy metals denoted that post-monsoon metal concentrations were lesser compared to the pre-monsoon due to dilution effect. Modified Contamination Degree (MCD) indicated that 45% of pre-monsoon and 25% of post-monsoon samples were classified under extremely polluted category. Heavy metal pollution index (HPI) showed that all the regions fall under highly polluted category except ‘Region I’ where 20% of samples were under safe category during the pre-monsoon, whereas 9%.28%. 17% and 26% of samples in Regions I, II, III and IV were highly polluted during the post-monsoon
Table 1
Descriptive statistics of heavy metals measured in Noyyal River.

<table>
<thead>
<tr>
<th>Pre-monsoon - 2019</th>
<th>Parameters</th>
<th>Cr</th>
<th>Pb</th>
<th>Ni</th>
<th>Cd</th>
<th>Cu</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region I</td>
<td>Min</td>
<td>0.010</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.002</td>
<td>0.112</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>1.740</td>
<td>0.142</td>
<td>0.120</td>
<td>0.078</td>
<td>0.080</td>
<td>6.700</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>0.198</td>
<td>0.029</td>
<td>0.031</td>
<td>0.019</td>
<td>0.032</td>
<td>1.717</td>
</tr>
<tr>
<td>Region II</td>
<td>Min</td>
<td>0.048</td>
<td>0.001</td>
<td>0.001</td>
<td>0.003</td>
<td>0.005</td>
<td>0.250</td>
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<td>1.547</td>
<td>1.214</td>
<td>1.145</td>
<td>0.124</td>
<td>1.214</td>
<td>8.120</td>
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<tr>
<td></td>
<td>Average</td>
<td>0.563</td>
<td>0.137</td>
<td>0.179</td>
<td>0.062</td>
<td>0.125</td>
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</tr>
<tr>
<td>Region III</td>
<td>Min</td>
<td>0.021</td>
<td>0.010</td>
<td>0.006</td>
<td>0.021</td>
<td>0.048</td>
<td>0.760</td>
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<tr>
<td></td>
<td>Max</td>
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<td>0.544</td>
<td>0.070</td>
<td>0.874</td>
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<td>6.000</td>
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<tr>
<td></td>
<td>Average</td>
<td>0.618</td>
<td>0.121</td>
<td>0.025</td>
<td>0.168</td>
<td>0.071</td>
<td>3.116</td>
</tr>
<tr>
<td>Region IV</td>
<td>Min</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.012</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>0.921</td>
<td>0.178</td>
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<td>0.052</td>
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<tr>
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<td>Average</td>
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<th>Post-monsoon 2020</th>
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<td>0.001</td>
<td>0.002</td>
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<td>0.030</td>
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<td>Average</td>
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<td>0.023</td>
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<td>Region III</td>
<td>Min</td>
<td>0.018</td>
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<td>0.001</td>
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<td>0.030</td>
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<tr>
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<td>0.074</td>
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<td>0.106</td>
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<td>0.007</td>
<td>0.026</td>
<td>2.024</td>
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</tbody>
</table>

Use Proper Colours

Fig. 2: Spatial distribution of heavy metals in the Noyyal River.

Pre & Post Monsoon Seasons
Effects of COVID-19 pandemic lockdown on microbial and metals contaminations in a part of Thirumanimuthar River, South India: A comparative health hazard perspective

D. Karunanidhi, P. Aravinthasamy, T. Subramani, Raj Setia

ARTICLE INFO

Editor: Dr. Rinklebe Jörg

Keywords:
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River water quality
Heavy Metal Pollution Index
Human health hazards
Thirumanimuthar River
South India

ABSTRACT

Twenty-two water samples from the Thirumanimuthar River course in southern India were collected before COVID-19 lockdown and during COVID-19 lockdown periods and were analyzed for microbiological parameters (fecal coliform bacteria, total coliform bacteria, Escherichia coli, and fecal streptococci) and heavy metals (Fe, Mn, Zn, Cu, Cd, Ni, Pb and Cr). The lockdown has decreased microbial populations and heavy metals. Fe, Cu, Cd, Ni, Pb and Cr exceeded the drinking water limits, respectively, in 77%, 45%, 27%, 18%, 9% and 91% of the pre-lockdown samples. During the lockdown period, Fe, Cu and Cd concentrations in 23% and Cr in 50% of the samples exceeded the limits. Heavy Metal Pollution Index (PMI) expressed that 27%, 64% and 9% of the pre-lockdown samples represented ‘low’, ‘medium’ and ‘high’ pollution categories, respectively, but 68% and 32% of the lockdown period samples represented ‘low’ and ‘medium’ categories, respectively. The Metal Index (MI) exposed that all samples of pre-lockdown were under the seriously affected category, whereas 54% and 46% of lockdown samples were under strongly and seriously affected categories, respectively. Health risk evaluations...
Comparison of Results Before & During Lockdown

Suitable Colour (Green’ Yellow & Red)

Index Maps

Sample Collection Spatial Data/ Map

Table 2

Heavy metal Pollution Index (HPI) and Metal Index (MI) of water samples collected from the Thirumanimuthar River before and during COVID-19 lockdown.

<table>
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<th></th>
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<td>HPI</td>
<td>109</td>
<td>80</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>TM1</td>
<td>98</td>
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<td>TM22</td>
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</tr>
<tr>
<td>Mean</td>
<td>109</td>
<td>92</td>
<td>13</td>
<td>7</td>
</tr>
</tbody>
</table>

Fig. 1. Study area and sampling locations in the Thirumanimuthar River course.

Legend
- Sampling points
- Drainages
- Study area boundary

Elevation (m)
- High: 659
- Low: 219

Fig. 3. Spatial distribution of Heavy metal Pollution Index (HPI) in the Thirumanimuthar River course (a) before COVID-19 lockdown, (b) During COVID-19 lockdown.
COVID-19 lockdown impacts on heavy metals and microbes in shallow groundwater and expected health risks in an industrial city of South India

P. Aravinthasamy, D. Karunanidhi, K. Shankar, T. Subramani, Raj Seta, Prosun Bhattacharya, Sayani Das

Abstract

In this investigation, the positive impact of COVID-19 lockdown on heavy metals concentration and biological parameters in the shallow groundwater samples of Coimbatore city of South India was ascertained. The groundwater samples (n=15) were obtained from shallow open wells during before lockdown (24–25 February 2020) and after lockdown (3–6 June 2020) periods. After lockdown, the number of samples crossing the cutoff limit had considerably decreased (Mn from 2 to 0 mg L⁻¹, Ni from 13 to 10 mg L⁻¹, Cr from 3 to 5 mg L⁻¹ and Pb from 19 to 5 mg L⁻¹). The heavy metal pollution index (HPI) revealed that 176.75 km² (67.4%) and 83.55 km² (22.6%) areas fell under unsuitable and very poor categories, respectively, during the pre-lockdown period, whereas 180.23 km² (52.6%), 119.08 km² (45.5%) and 4.59 km² (1.2%) areas fell under very poor, poor and good categories, respectively, during the post-lockdown period. Similarly, Fe, Pb and Ni concentrations of the wells had decreased drastically due to the pandemic lockdown. Therefore, the shutdown of small and large-scale industries during the lockdown period had improved the groundwater quality. The health risk assessment showed that 93%, 37% and 80% of pre-lockdown samples, and 58%, 10% and 73% of post-lockdown samples presented non-carcinogenic risks (HI > 1) for children, female and male categories, respectively.

2.5. Health risk assessment

The HQ values were above 1 for Ni, Cr and Pb, and were in the order: Pb > Cr > Ni. Before lockdown, the mean HQ among children was 0.0015 for Fe, 0.02086 for Mn, 0.4563 for Ni, 1.0138 for Cr and 0.10971 for Pb. The mean HQ among female category was 0.00103 for Fe, 0.121 for Mn, 0.2712 for Ni, 1.3976 for Cr, and 0.10971 for Pb. The mean HQ among male category was 0.00018 for Fe, 0.14011 for Mn, 0.6709 for Ni and 1.4499 for Pb.
Geospatial Technology for Defense & Intelligence Purpose

Talk of the Day
War Planning (Army, Navy & Air Force)
Multifunctional Robots in Battle Field

Geospatial Artificial Intelligence (Geo.AI)

Future R & D
DST-NRDMS (Govt of India) Funded National Level Training Programme on "Geospatial Technologies"
Organized from 08-Feb-2017 to 10-Feb-2017
Fig. 5 Proportion of groundwater-related articles in related subject areas/disciplines

Fig. 6 Top 20 most productive authors publishing in the groundwater field from 1970 to 2020

authors (21), appearing in Cluster 2. Following Mukherjee A., Ramanathan A.L. (from Cluster 2) co-authored with 20 other authors and Ahmed S. (from Cluster 3), co-authored with 19 authors. From this network analysis, Prasanna M.V. and Chidambaran S. from Cluster 5 (shown in purple color) co-authored in highest number of groundwater-related articles (45). Thus, it shows that in the field of groundwater research, researchers have formed an academic pattern of close contact and mutual cooperation.

Keyword analysis

For this study, only author keywords have been considered, and keyword cloud and frequency analysis were conducted to present a general overview of the most prevalent research themes for the South and Southeast Asian countries.

Of the total 10,240 keywords, 185 keywords (~2%) have been shortlisted, which have been used more than fifteen times in the groundwater-related articles. The most frequently used keywords for the 50 years of this study are illustrated in Fig. 8, and the top 20 keywords are listed in Table 5. Except for groundwater, which is the top search keyword for this study, the top five most frequently used keywords are “Groundwater quality,” “Geographic information system,” “India,” “Arsenic,” and “Fluoride.” Interestingly, from the country-level perspective, India and Bangladesh are the two countries occurring the most frequently within the keywords, possibly for India it is due to a relatively higher share of publications in comparison to other countries. Additionally, both of these countries face serious groundwater challenges due to agricultural
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Thank you

Any questions?