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Coldwater Resource Mapping using Geospatial tools

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Directorate of Coldwater Fisheries Research

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On

Coldwater Resource Mapping Using Geospatial Tools

(19-21 Feb, 2025)

Editors

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Organized by

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Lastly, we extend our gratitude to the participants for their keen interest in learning and applying geospatial tools for sustainable fisheries resource management. We hope this manual serves as a valuable resource in their professional journey.

(Editors)

Foreword

ICAR-Directorate of Coldwater Fisheries Research, Bhimtal, is one of the country's premier institute for undertaking research, development, capacity building, and extension activities in the Himalayan region, focusing primarily on the Coldwater fisheries and aquatic resources. The Directorate has carried out a strenuous exercise towards developing a roadmap for the country's coldwater fisheries and aquaculture, especially trout farming. Through its outreach and extension programs, the Directorate has contributed substantially to the development of marginal and weaker sections of the society in the Himalayan region.

In today's rapidly advancing technological landscape, integrating geospatial tools such as remote sensing (RS) and geographical information systems (GIS) has become indispensable for sustainable resource management. The fisheries sector, particularly coldwater fishery resources, is no exception. These modern tools enable precise mapping, monitoring, and sustainable planning, ensuring the efficient utilization and conservation of aquatic ecosystems. Recognizing the growing need for capacity building in geospatial applications for fisheries, this training manual has been developed to serve as a comprehensive guide for researchers, academicians, students, and professionals. It provides an in-depth understanding of Remote Sensing, GIS, and GPS technologies and their applications in coldwater fisheries resource management. This manual is designed to be hands-on and practical, enabling trainees to develop the necessary spatial data analysis and decision-making skills. The step-by-step guidance on creating maps and utilizing GIS software ensures learners can confidently apply these techniques in real-world scenarios.

I extend my appreciation to the authors and contributors for their efforts in compiling this valuable resource. I hope this manual will empower participants with the knowledge and technical expertise required to harness geospatial technologies for the sustainable development of coldwater fisheries and other natural resource management initiatives.

I wish all the participants a productive and insightful learning experience.

(Pramod Kumar Pandey)

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Contents

Coldwater fishery Resources of India: Strategy for sustainable utilization.

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Introduction

On a global level, mountains are the world's largest repositories of biological diversity. Mountain regions are characterized by the presence of cold waters, many of which harbour fish and support largely subsistence fisheries. India has significant cold-water/hill fishery resources of which some are suitable for food, and few others have sport and ornamental value. These extend from north western to north-eastern Himalayan region and some parts of Western Ghats, encompassing about twelve states. The term 'coldwater' generally refers to the aquatic ecosystem, which maintains thermal and oxygen levels for well-being of trouts, mahseers, snow trouts and other minor species. The temperature generally falls within the tolerance limits of trouts and salmons belonging to family salmonidae (<20°C). A number of physical, chemical, geochemical and biological parameters of different water bodies e.g. water temperature, dissolved oxygen, velocity, turbidity, substratum, trophic status, food availability etc. influence the distribution and abundance of various species of coldwater fisheries. In Indian subcontinent, coldwater fishes are generally the natives of the Himalayan and subHimalayan zones in the north and watersheds draining the southern slope of Deccan plateau (Sunder et al., 1999). From a North American perspective, Lyon et al. (2009) have distinguished cold waters from warm waters on the basis of mean summer temperature and the maximum mean daily temperature (Table 1). In cold waters, the maximum mean daily temperature remains lower than or nearly equals the mean summer temperature of warm waters. The atmospheric temperature declines with the elevation above the mean sea level as well as with the latitude. In India, the situation is a bit complex as the climate is greatly influenced by the monsoons and the Himalayan mountain ranges. Because almost the entire country lies within the tropical and subtropical zone (below 38° N latitude), and is well protected by the high Himalayan mountain ranges against the cold winds from the north, the mean daily temperature during the summer merely drops to 20 °C. Therefore, the altitude is the main determinant of the cold water conditions in the Himalayan belt. Generally, the aquatic systems lying above 2500 m above sea level are considered to constitute the coldwater habitats. It is noteworthy that the mean temperature of water in all Kumaon lakes during the summers remains above the 20 °C threshold, the maximum temperature rises well above 25 °C (Johri et al., 1989). Thus, according to the criteria of Lyons et al. (2009), these lakes do not qualify to be coldwater lakes. However, Sehgal (1999) and Raina and Petr (1999) included the aquatic habitats at elevations far lower than 1500 m also in their accounts of coldwater fish and fisheries. In general view, a distinction between cold and warm waters must be based on the temperature thresholds of fish and other important aquatic biota in the Himalayan region. This is an important area for research in India (Gopal, 2012).

Table 1: Thermal classification of streams in Wisconsin (Lyons et al., 2009)

S. No.	Class	MeanJulyAugust	Mean July	Max. DailyMean
1.	Coldwater	<17.0	<17.5	<20.7
2.	Cool water	17.020.5	17.521.0	20.724.6
3.	CoolTransition	17.018.7	17.519.5	20.722.6
4.	Warm Transition	18.720.5	19.521.0	22.624.6
5.	Warm water	>20.5	>21.0	>24.6

Coldwater fisheries occupy an important place in fisheries sector of India. The country is bestowed with vast and varied coldwater / hill fishery resources which are spread over the Himalayan and peninsular regions as upland rivers, streams, high and low altitude natural lakes and reservoirs. There are around 10,000 km long streams and rivers, 20,500 ha natural lakes, 50,000 ha of reservoirs, both natural and manmade, and 2500 ha brackish water lakes in the high altitude (Mahanta & Sarma, 2010).This diverse natural resource-base, wide climatic diversity *vis-à-vis* altitude are conducive to conserve and rear different fish species, developing domestic market for high value fish and growing interest of people aquarium pet keeping and eco-tourism including angling in different altitudinal regions of the country.

The coldwater rivers and hill streams are known for their high velocity, waterfalls, rapids, cascades, deep pools and substratum comprising with bedrock-boulder-sand.These water resources harbour 258 fish species belonging to 21 families and 76 genera in the country of which 203 are recorded from the Himalayas while, 91 from the Deccan Plateau (Sehgal, 1999).The North Eastern states have also rich Ichthyo faunal diversity.Of which majority are food fishes while others have potential ornamental and sports value. In the Indian Himalayas, the cultivation of fish contributes little to the overall freshwater fish production.Virtually, every facility created for fish cultivation in the Indian Himalaya produces fish for stocking into the streams and lakes primarily to meet the requirements of sport fishing.

The present exploitation of fishery resources in upland regions comes mainly in the form of capture fisheries serving as subsistence fishery, though fish production through culture practices is also gaining popularity. At present, the contribution towards national fish production from the upland sector is very meagre. This is attributable to several constraints such as low productivity of upland waters, comparatively slow growth rate in majority of fish species, low fecundity and and selective fishing gears in operation. The ICAR-Directorate of Coldwater Fisheries Research (DCFR) being a national organization is catering the research and development need of the upland waters has achieved manifold success in the management of fish genetic diversity and establishment of aquaculture in the hill regions of India.

Himalayan Aquatic Resources and Environment

The Indian Himalayan region spreading between 21º57' to37º5' N latitudes and 72º40' to 97º25' E longitudes with 250-300 km across stretches over 2,500 km from Jammu and Kashmir in the west to Arunachal Pradesh in the east. These mountainous region cover partially or fully twelve states of India, viz., Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim,Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, Meghalaya and hills of Assam and West Bengal. The region has atotal geographical area of about 5,33,604 km^2 being inhabited by 3,96,28,311 people, representing about 16.2% of total area and 3.86% of total population of India, respectively.

The region is vast, uneven and versatile inhabiting rich floral and faunal diversity and is divided into eastern Himalaya, central Himalaya and western Himalaya, each with different physiography and faunal diversity. Topographically, Himalayas from South to North is divided into four parallel & longitudinal mountain belts (Table 2).

Based on the altitudinal gradient, the agro-climatic zones in the Indian Himalayan region are broadly classified as warm sub-tropical (<800m) to arctic zone (>3,600m).

The Indian Himalayan region has enormous fresh water resources in the form of streams, rivers, lakes and glaciers. It is drained by 19 major rivers of which the Indus, the Ganges, and the Brahmaputra are exemplary ones. The Indus and the Brahmaputra are the longest, each having a mountain catchment of about 160,000 km^2. Five rivers (Jhelum, Chenab, Sutlej, Ravi, Beas) belong to the Indus system, of which the Beas and the Sutlej have a total catchment area of 80,000 km^2; Nine (Ganga, Yamuna, Ram Ganga, Kali-Sharda, Karnali, Rapti,Gandak, Bhagmati and Kosi) belong to the Ganga system, draining nearly 150,000 km^2; and three (Tista, Raidak and Manas) belong to the Brahmaputra system, draining another 110,000 km^2. Most of these rivers flow in deep valleys until they exit the mountains (Sehgal, 1999).

Table 2: Major divisions of Himalayan region (Sehgal, 1999)

S.No.	Division	Features
1	The Greater Himalayas (Himadri)	Longest and continuous, mostly north part of Nepal and parts of Sikkim. Average altitude of about 6100 m (20,000 ft) asl.
2.	Lesser Himalayas (Himanchal)	In the south and north of Siwalik. Average altitude ranging from 3700m (12,000) - 4500m (15,000 ft) asl.
3.	Siwalik (Outer Himalaya)	Siwalik is the lowest and narrowest section of Himalaya. Average altitude about 900m (3000ft) to 1200m (4000 feet) asl.
4.	Trans-Himalayas	Stretches across Himalaya from West to East for about 1,000 km. Average altitude varies from 4500 to 6600 m asl.

There are numbers of lakes, of different sizes, situated in the mid and high altitudes of Himalayan regions with diverse origins, such as retreat of glaciers, landslides. In the Great Himalayan and Trans-Himalayan region lakes are present at high altitude, with the highest lake situated at 5297 m asl. Jana (1998) listed 13 lakes situated from 3400 m to 5297 m, some of them being brackish or saline. Freshwater lakes in Kashmir Valley are believed to have originated as oxbow lakes of the Jhelum River (Raina, 1999). Large lakes having 15,300 ha of surface area are located at middle altitude (1537 to 1587 m) in the State of Jammu and Kashmir while Kumaon lakes situated (1237 to 1930 m asl) in the state of Uttarakhand are much smaller, with the largest only 72 ha. In Himachal Pradesh Coldwater lakes are situated between 1306 and 4815 m asl. The state wise water resources including rivers and canals total replenishable ground water, major rivers, major wetlands and fish diversity are given in Table 3.

Table 3: State wise water resources in the region

State	Length of rivers/canals (thousand km)	Water bodies (lakh hectare)	Total replenishable ground water	Major rivers	Major wetlands	Recorded Fish diversity
Jammu & Kashmir	27.78	0.30	4425.84	Indus Zanskar Shyok Jhelum Lidder Bringhi Chenab Tawi etc	Dal Wular Mansbal Anchar Gangbal Vishansar Pangong Tso,Marsar Gadsar etc	26
Himachal Pradesh	3.00	0.43	365.81	Spiti Sutlej Beas Ravi etc	Renuka Lam Dal Kareri Khajiar Chandertal	82
Uttarakhand	2.69	0.20	-	Alaknanda Dhauliganga Pindar Mandakini Bhagirathi Ramganga-W Kosi Bhilangna	Nainital Bhimtal Sattal Naukuchiatal Garudtal Khurpatal Shyamlatal	67
Sikkim	0.90	0.03	-	Tista Lachung Chhu Rongni Chhu TolungChhu Upper Rangit	Memencho Tsomgo Elephant Lake Khora Chhobuk lake	23
Meghalaya	5.60	0.10	539.66	Digaru Kopili Myntdu Piyain Someshwari	Thadlaskein Umang Umiam Wards lake	165

Tripura	1.20	0.17	663.41	Burima Gomati Manu Dhalai Khowai Haora	Dumboor Amarsagar Rudrasagar Kamalasagar Khowra Kalyansagar Jagannath dighi	134
Mizoram	1.40	0.02	-	Tlawng Tlau Chhimtuipui Tuichang Tuivawl Teirei	Tamdil Palak Rungdil Rengdil	48
Manipur	3.36	0.46	3154.00	Barak Iril Nambul Tiau	Ikop pat Loktak Pumlen pat	121
Nagaland	1.60	0.67	724.00	Doyang Dhansiri Dikhu Tizu Milak Langlong Likimro	Shilloi Dzudu Tsumang Totsu Wozhu l Lake aizuto	68
Arunachal Pradesh	2.00	0.04	1438.50	Dhibang Dirang Subansari Kameng Tawang Chu	Nagula Seri Pangateng tso, Tensing Madhuri Lake Ganga Lake	167

[**Source**: Hand book on Fisheries Statistics 1996, Department of Agriculture and Cooperationand Ground Water Statistics 1996, Central Ground Water Board] mcm: Million cubic Metres Water bodies include reservoirs, lakes, ponds, tanks, beels and oxbow, etc. Data for the hill districts of Assam and West Bengal are not available separately; Shanawaz ali-2010; Singh, A.K., 2015; Kumar et al-2017]

Fish biodiversity

The water bodies of the Himalayan region inhabit diverse kind of fish fauna. Out of total fish fauna available in India 17% fishes were documented from the mountain ecosystem establishing the status of the area as a centre of origin and evolution of biotic forms (Ghosh, 1997).

The coldwater fisheries harbour 258 species belonging to 21 families and 76 genera. Out of these, the maximum of 255 species are recorded from North-East Himalaya, 203 from the west and central Himalaya and 91 from the Deccan plateau (Sehgal, 1999). Singh et al, 2014, reported that the vast mountain fishery resources of India inhabits around 258 fish species distributed in the Himalayan and peninsular region of the country of which indigenous mahseer, snow trout, exotic trout and common carp are commercially important. About 36 species of freshwater fishes (out of 1,300) are endemic to the Himalayan region (Ghosh, 1997). For the whole Himalayas, 218 species are listed (Menon, 1962). The distribution of fish species in the Himalayan streams depends on the flow rate, nature of substratum, water temperature and the availability of food (Table 4). The species distribution and composition in the upper reaches and lower reaches is different owing to the differential flow rates and substratum variability. The eastern Himalaya, drained by the Brahmaputra has agreater diversity of Coldwater fish than the western Himalayan drainage

Table 4: Important Coldwater Fish Species of Indian Himalayas

Important Coldwater Fish Species		
Snow trout:	**Exotic carps:**	**Barils/Minnows/Catfishes/ Loaches**:
Schizothorax richardsonni	*Cyprinuscarpio var. specularis*	*Barilius bendelisis*
Schizothoraichthys curvifrons	*C. carpio var. communis*	*B. bakeri*
S. esocinus	*C. Carpio Var. nudus*	*B. vagra*
S. niger	*Ctenopharyngodon idella*	*B. barila*
S. plagiostomus	*Hyphthalmichthys molitrix*	*Raimas bola*
S. progastus	*Carrasius carrasius*	*Danio devario*
Lepidopygopsis typus	**Minor carps:**	*Botia birdi*
Diptychus maculatus	*Labeo dyocheilus*	*B almorhae*
Mahseer:	*Labeo dero*	*Glyptothorax pectinopterus*
Tor putitora	*Chagunius chagunio*	*G. brevipinnis*
T. tor	*Crossocheilus latius latius*	*G. stoliczkae*
T. khudree	*Gara gotyla,*	*Pseudechenesis multifasciatus*
Neolissochilus hexagonolepis	*G. hughi,*	*Nemacheilus rupecols*
Neolissochielus wynaadensis,	*G. lamta,*	*N. multifasciatus,*
Naziritor cheylinoides	*Puntius conchonius,*	
Exotic trouts:	*P. ophiocephalus,*	
Onchorhynchus mykiss	*Semiplotus semiplotus*	
Salmo trutta fario		

The commercially important Indian coldwater species are *Tor tor, T. putiora, T. mosal, T.progeneius, T. khudree, T. mussullah, T. malabaricus, Naziritor chelynoides, Neolissochielus wynaadensis, N. hexagonolepis, Schizothoraichthys progastus, S. esocinus, Schizothorax richardsonii, S. plagiostomus, S. curvifrons, S.micropogon, S. kumaonensis, Barilius bendelisis,B. vagra, B. shacra, B. (Raiamas) bola, Bangana dero, Labeo dyocheilus, Crossocheilus periyarensis, Semiplotus semiplotus, Osteobram abelangeri, Garra lamta, Garra gotyla gotyla, Glyptothorax pectinopterus, G. brevipinnis, G. stoliczkae, Chagunius chagunio, Labeo dero, L. dyocheilus and Lepidopygopsis typus (*Sehgal, 1999; Sunder et al., 1999; Jena and Gopalakrishnan, 2012; Sehgal, 2012).

Mahseer is a group of game fish that belongs primarily to the genus Tor, but also includes some species of the genus *Neolissochilus* (e.g. Chocolate mahseer *Neolissochilus hexagonolepis*). Schizothoracines (family Cyprinidae and sub-family Schizothoracinae) on the other hand, contribute to an economically significant group of hill stream fishes all along the Himalayan belt especially from Kashmir Himalaya. Out of about 258 cold water fish species (both indigenous and exotic) reported from Indian uplands, 17 members of snow-trout's (locally known as "Asela, Sela or Rasella" in Uttarakhand, "Gulgali" in Himachal and "Koushar gad" in Kashmir Himalayas) have been recognized by many authors (Talwar and Jhingran, 1991; Tilak, 1987 and Sundar et al., 1999). Of these, 10 species belong to genus Schizothorachthys species being *(niger, esocinus, curvifrons, longipinnias, micropogon, planifrons, hugelli, labiatus, nasus, progastus*), two to genus Schizothorax (species being richardsonii and kumaonensis) and one each to *Diptychus (maculates), Gymnocypris (biswasi), Lepidopygopsis (typus), Ptychobarbus (conirostris), Schizopygopsis (stoliczkae).* Only *Lapidopygopisis typus* is restricted to Periyarlake (Western ghats), Kerala. All other species are available from Jammu and Kashmir region. *Schizothorax richardsonii* is most common and widely distributed species in Himalayan belt (Sehgal, 1999).

Mountain fisheries and hill aquaculture

The present exploitation of fishery resources in upland regions comes mainly from capture fisheries, though fish production through culture practices is gaining momentum. Fish production in hill region is confined to inland waters such as river streams, lakes and reservoirs. The production from such facilities is not up to the mark possibly due to several constraints such as low productivity of upland waters, comparatively slow growth rate in almost all fish species and low fecundity in fishes.

Culture of coldwater fish in the Indian Himalayas has largely focussed on the production of stocking material for rivers and streams, and some lakes. Until recently, carps, mahseer, snow trout, and rainbow trout dominated the fish cultured for fish seed production, and to a much lesser extent for table fish production. Today, the available technologies allow the culture of a number of exotic and indigenous coldwater fish species in the Indian Himalayas. The most commonly cultured ones include exotic species such as Rainbow trout, Brown trout, Common carp , and the indigenous fishes such as Mahseer (Golden and Choclate), and Schizothoracines (*Schizothoraichthys esocinus*, *S. progastus*, *Schizothorax richardsonii*, *S. niger* and *S. curvifrons*). Among these *Tor putitora*, *S. progastus* and *S. richardsonii* are preferred for fishery because of their wide range of distribution in the Himalayas.

Catches of snow trout have been reported to the tune of 67-74% from north-western Himalayas; 59-67% from Uttaranchal Himalayan streams/rivers, however, by and large their overall size frequency have gone down by 10-20% over the years (Sunder, 2005). Besides indiscriminate killing, destructive fishing methods and ecological degradation the inherent biological factors of low fecundity and long hatching period have further added its decline in the natural streams. Various *in-situ* and *ex-situ* conservation efforts have been identified based on the resource assessment of Schizothoracine. Although some success have been achieved in artificial propagation of snow trout species such as *S. richardsonii* (Vass, 2012) and *S. niger* (Najar *et al*., 2014), in the recent past, the culture of schizothoracines is still in its experimental stage. There is still work to be done on schizothoracine seed production to achieve a fully viable fingerling stage ready for release into rivers and lakes

Mahseers (*Tor* spp.) of the family Cyprinidae are regarded as one of the best sport fish and also a sought-after food fish. In the Indian Himalayas mahseer stocks have sharply declined, due to man-caused deterioration of the environment and overfishing. Owing to its endangered status, mahseer conservation has become utmost priority for enhancing its natural population in the streams and rivers of Himalayas. Earlier seed of mahseer was collected from natural sources but recently seed has been produced through artificial propagation. However, with the devoted efforts of ICAR-DCFR, the artificial propagation of the fish is possible now. The protocol for breeding and propagation has been standardised wherein the brood stock is collected from natural grounds in rivers, lakes etc are stripped of their eggs and milt and fertilized eggs are incubated in specially developed flow through hatchery. This technique enables the production of pure and healthy seed in captive condition. This seed can be used for augmentation of natural stock through ranching and aquaculture of this species.

In the upland waters, Chinese carps are commonly cultured in the mid-Himalayan region as the candidate species for polyculture. Culture of rainbow trout (*Oncorhynchus mykiss* and brown trout (*Salmo trutta fario*) in the hill states have been considered as the promising species for mountain fisheries development in India. Today, farming of Rainbow trout is being carried out on several fish farms in Jammu and Kashmir, Himachal Pradesh, Uttrakhand, Arunachal Pradesh and Sikkim. The siting of these aquaculture facilities was based on the availability of water in required quantity and quality, i.e. from rheocrene springs and snow-melt/glacier-fed streams.

Most farms receive water supply from snow-melt/glacier-fed streams. A total of 30 trout hatcheries with an estimated eyed ova production capacity of 13 million are present in the country which have been mostly established by the various state governments and also with the assistance of central government schemes. The state of Jammu & Kashmir and Himachal Pradesh are forerunner in promoting rainbow trout farming in private sector. The highest trout producer state in India is Jammu & Kashmir with a table size trout production of 260 MT and 8 million trout ova production. The Himachal Pradesh is second highest producer (168 MT) in the country.

Challenges

The climate change is a worldwide phenomenon. It refers to any significant change in climate through temperature and rainfall pattern etc. for an extended period of decades or longer, as a result of natural processes and anthropogenic activities. As global warming continues to increase the atmospheric temperature, it will lead to a continuous shift of zero temperature line (snow line) towards higher altitudes. Climate change is affecting Coldwater resources and their fisheries through its impact on flow regimes of streams, phenological changes, food chain, micro habitats and overall productivity. The changed eco-climatic conditions would adversely impact the pristine feeding and breeding grounds of the native coldwater fish species their population, maturity condition and spawning and related vital life cycle phenomenon.

Management strategies for sustainable utilization

There is a need of introduction of large scale farming to bring the mountain fishery and aquaculture in India on international scenario. Coldwater fisheries for livelihood and industry are the two modern concepts which aim to provide sufficient fish locally at cheaper price as nutritional security and to export the fish and fishery products to earn the foreign currency. .

Following points need to be taken care of for managing the coldwater resources in a sustainable manner.

1. To develop the coldwater sector in an integrated manner, mapping of the fishery resources in mountain/ hill region needs to be taken up on priority basis
2. Production enhancement, either species or stock, in lentic and lotic systems by means of sustainable intensive culture practices needs to be taken up.
3. Horizontal and vertical expansion of fish culture activities through identification of, suitable land/water bodies using modern tools of technology and their micro climatic conditions should be brought under any of the three pronged fish farming practices.
4. Regular monitoring of reproductive biology of economically important fish spec ies so as to suggest remedial measures for depleting population.
5. Extensive conservation and bio monitoring of all coldwater resources in time and space to assess threat perspectives in relation to biodiversity.
6. Conservation and rational exploitation of resources, which are the backbone of fish and fisheries in the region particularly at the high altitude areas.
7. Development of sport/recreational fishery for tourism and employment generation.
8. Ownership of resources needs to be decided
9. A balanced strategy for lakes, for tourism and fishery development needs to be formulated.
10. Location specific legal framework needs to be formulated and implemented religiously.
11. Fish breeding and nursery sites need special protection by declaring them “Restricted or No-fishing zones”
12. Education, training and extension support to the hill communities for resource conservation and sustainable utilization.
13. Promoting awareness on sustainable use of mountain natural resources (aqua-gardening) and conservation of biological diversity for maintaining mountain ecosystems.

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Remote Sensing: Types and Applications

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Introduction

Remote sensing is a technology for acquiring information about the earth's surface without actually being in contact with it. This is done by sensing and recording reflection or emitted energy & processing, analyzing, and applying that information. In this technology, special cameras collect images from the objectives and then sense the images accordingly to provide information and sense things about the earth.

It is the science & art of obtaining information about an object, area, or phenomenon (earth's surface) through the analysis of data acquired by a device that is not in direct contact with the object, area, or phenomena under the investigation. It helps in essential global matters such as climate change, global warming, etc.

In other words, remote sensing can be defined as the science and art of obtaining information about an object, area, or phenomenon through satellite. The science & art of acquiring information about an object without entering into contact with it, by sensing or recording the reflected or emitted energy and processing, analyzing, and applying that information in remote sensing.

It is used in several fields like geography, geology, ecology, glaciology, hydrology, and oceanography. Special cameras present collect remotely sensed pictures, which helps the researchers "sense" the things about the Earth and other planets. Remote sensing when combined with GIS technology helps in important database operations like queries with maps, and statistical analysis.

This technology started with the invention of the camera. Initial photographs were just simple photographs, but the intention of taking the Earth's images for its graphic mapping arose during the year 1840 and due to this concept scientists started to fix cameras on balloons just to take a wide range of images. During the era of WWI, cameras were placed on airplanes just to get an aerial view image of landslides. Only during the space age era did satellite remote sensing develop. It was used for the objective of imaging the Earth's surfaces as well as sensing other spacecraft, and other planets.

Components

There are three essential components of remote sensing system –

- Remote sensing platforms
- Remote sensing sensors
- Remote sensing orbits

Remote Sensing Platforms

A platform is the vehicle or carrier for remote sensors. A platform is needed to hold the instrument and there are three types of platforms in Remote Sensing –

- Ground based platform
- Airborne platforms
- Space borne platform

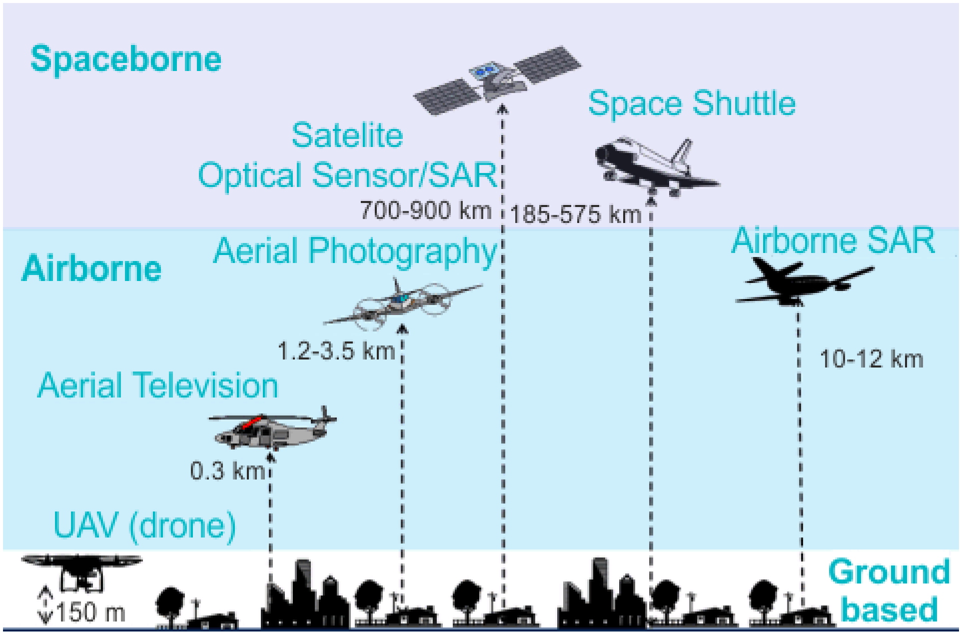

Fig: Different types of platforms used in remote sensing

1. Ground Based Platform

Ground based platform used to record detail information about the surface very closely. These are the ground level platforms such as cranes and towers. Some example of ground-based platform are:

- Ground vehicle
- Tower
- Air balloon
- Kite

The height of ground-based platform is up to 50 m or in the other words we can say that the ground-based platforms are found above 50 m from the Earth surface.

2. Airborne Platforms

They are used to collect very detailed images and facilities the collection of data over any portion of Earth's surface at any time but it is very expensive platform as compared to ground-based platforms. The height of airborne platform is above 50 km from earth surface. These are the aerial platforms such as :

- Aeroplane
- High altitude aircraft
- Helicopters

3. Space Borne Platform

Some examples of space borne platform are as follows:

- Rocket satellite space shuttle whose height is 250 to 300 km above from the Earth surface
- Space station which whose height is 300 to 400 km
- Low level satellite which is also known as polar satellite whose height is 700 to 1500 km
- High level satellites which are also known as geostationary satellites whose height is 36000 km above the Earth's surface

Remote Sensing Sensors

Remote sensors collect data by collecting the energy which is reflected from the Earth, it is based on sensor technology to detect, in order to observe the target the sensors are needed and classify the object. The classification of sensors are as follows:

- **Passive Sensors:** They detect natural energy(radiation) that is emitted or reflected by the object or scene being observed. Reflected sunlight is the most common source of radiation measured by passive sensors. The passive sensors detect the energy which is reflected from the environment.

- **Active sensors:** They transmit their own signal and measure the energy that is reflected and transmitted back or scatter back from the target. For example, radar sonar. So in general , they provide their own source of energy to illuminate the object which they observe.

Working

The various steps involved in remote sensing is given as follows:

1. **Energy source** - The first requirement for remote sensing is to have an energy source which illuminate or provide electromagnetic energy to the target of interest.

2. **Radiation and atmosphere -** As the energy travels from its source to the target, it will come in contact with or interact with the atmosphere it passes through; this interaction may take place a second as the energy travels from the target to the sensor.

3. **Interaction with the target -** Once the energy makes it way to the target through the atmosphere, it interacts with the target depending upon the properties of both the target & radiation

4. **Recording of energy by the sensors -** After the energy has been scattered by, emitted from the target, we require a sensor (remote-not in contact with the target) to collect and record the electromagnetic radiation.
5. **Transmission, reception and processing -**The energy required by the sensors has to be transmitted, often in electronic form, to receive and processing section where the data are produced into an image (hard copy & digital).
6. **Interpretation and analysis -**The proceed image is interpreted in two types visually and digitally. To extract information about the target which was illuminated.
7. **Application -** The final element of remote sensing process is achieved when we apply the information - we have been able to extract from the imagery about the target in order to better understand and reveal some new information.
8. **Electromagnetic radiation ---** electromagnetic radiation refers to the waves of the electromagnetic field, propagating through space, carrying electromagnetic radiant energy. It includes radio waves, microwaves, infrared, light, ultraviolet, X-rays, and gamma rays.

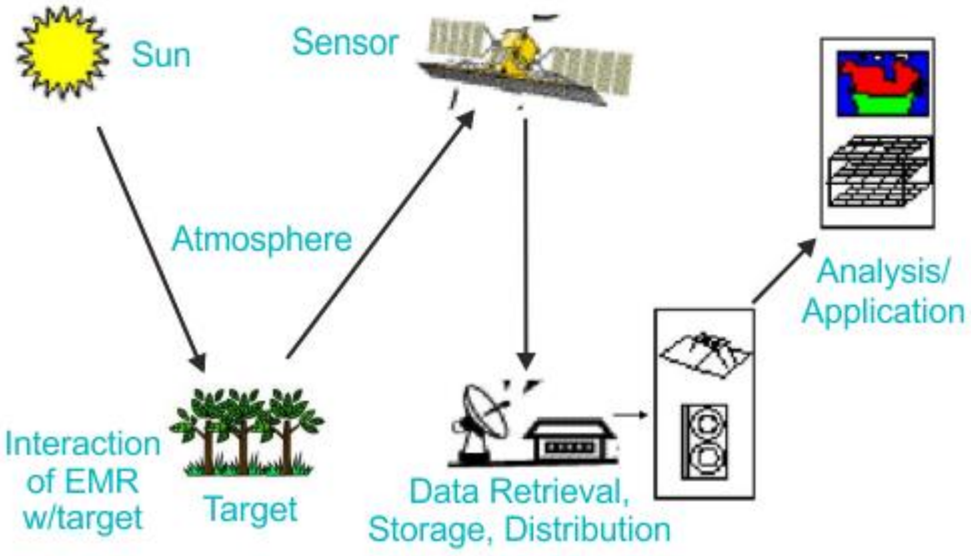

Fig: Elements involved in remote sensing

Remote Sensing Orbits

In remote sensing, orbits play one of the major components of remote sensing. The path followed by a satellite is referred to as its orbit. Orbit selection can vary in terms of altitude (their height above the Earth's surface) and their orientation and rotation relative to the Earth. Overall, low earth orbit is the best orbit for the purpose of remote sensing which is commonly used for communication and remote sensing.

Types of remote sensing orbits are as follows:

- Geostationary orbits

- Polar Orbit
- Sun -Synchronous

1. Geostationary Orbit

Satellites at very high altitudes, which view the same portion of the Earth's surface at all times have geostationary orbits. These geostationary satellites, at altitudes of approximately 36,000 kilometers, revolve at speeds which match the rotation of the Earth so they seem stationary, relative to the Earth's surface. This allows the satellites to observe and collect information continuously over specific areas. Weather and communications satellites commonly have these types of orbits

Fig: Geostationary Orbit

2. Polar Orbit

A polar orbit travels north-south over the poles and takes approximately an hour and a half for a full rotation. As a result, a satellite can observe the entire Earth’s surface (off-nadir) in the time span of 24 hours. Almost all the satellites that are in a polar orbit are at lower altitudes. Plus, they are often used for applications such as monitoring crops, forests and even global security.

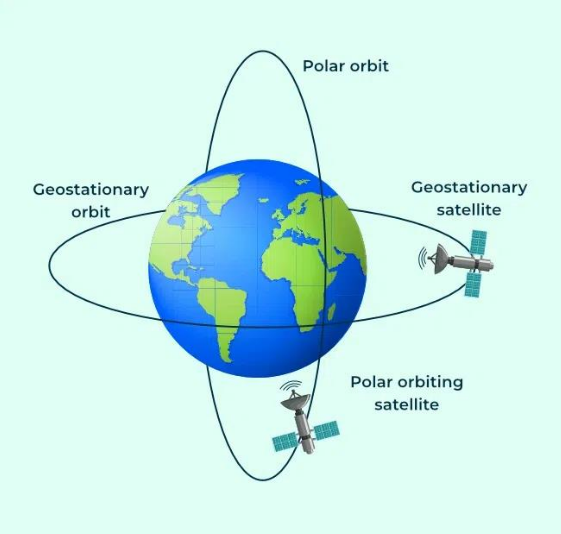

Fig: Polar orbit

3. Sun-Synchronous Orbit

These orbits allow a satellite to pass over a section of the Earth. Since there are 365 days in a year and 360 degrees in a circle, it means that the satellite has to shift its orbit by approximately one degree per day. These satellites orbit at an altitude between 700 to 800 km.

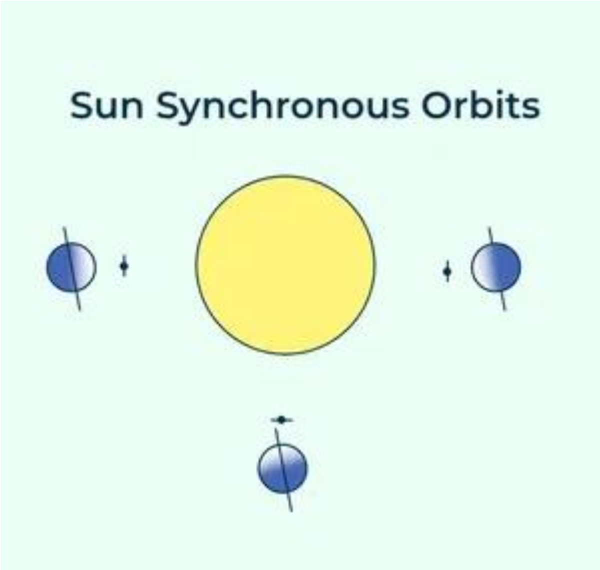

Fig. Sun Synchronous Orbit

Types of Remote Sensing

There are two type of remote sensing sensors which is based on the sensors are as follows:

- Passive sensors
- Active sensors

Passive Sensors

Passive sensors detect natural energy(radiation) that is emitted or reflected by the object or scene being observed. Reflected sunlight is the most common source of radiation measured by passive sensors. Sensing done via active sensors is called active sensing. For excitation, they often need extra electrical power. Only when the energy that naturally occurs is available can passive sensors be utilized to detect it, during the day can passive sensors gather data, electromagnetic energy is measured by the passive sensor.

The passive sensor is defenseless against an invading force. Sensors that are passive wait patiently for data requests. As a result of the stimulation, the passive sensor's transducer causes a change in a passive electrical quantity like capacitance, resistance, or inductance.

The passive sensor measures utilizing EM radiation that is naturally emitted within its field of view. Satellites used for remote sensing, such as SPOT-1 and LANDSAT-1, are examples of passive sensors.

Active Sensors

Active sensors transmit their own signal and measure the energy that is reflected and transmitted back or scatter back from the target. For example, radar sonar. Sensing done via passive sensors is called passive sensing. A transducer that is an active sensor directly produces electric current or voltage in response to external stimulus. The active sensor produces its own electromagnetic (EM) energy, transmits it toward the earth, and then collects energy reflected back from the planet. Electromagnetic (EM) radiation that has been received is used for measurement.

They self-destructs during hijack attempts and can take measurements at any time. Electromagnetic energy is measured and transmitted by active sensors. Regardless of whether the on-duty employees want the data or not, an active sensor actively communicates measurement to ground stations. It provides their own energy source for illumination. Example of active sensor like communication satellite, earth observation satellite, LISS -1, etc.

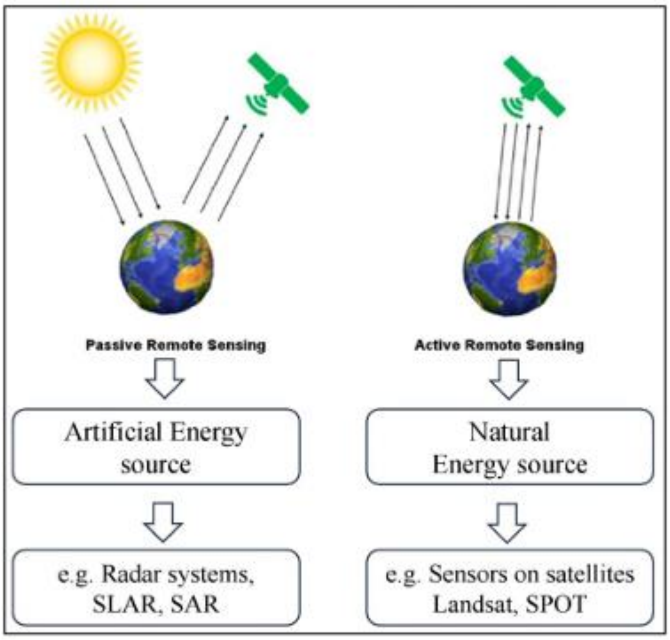

Fig: Types of remote sensing

Sensor Parameters

Various earth surface objects are intended to be identified and mapped using the data gathered by the remote sensors. As a result, we can state that the classification and mapping accuracy requirements are used to evaluate the sensor's performance. It is reasonable to anticipate that this will depend on the instrument's capacity to identify minute variations in the earth's surface's emittance and reflectance throughout a range of spectral bands for as few and as frequent objects as feasible. Resolution describes the numerous parameters that define these various types of sensor systems. The spatial, spectral, radiometric, and temporal resolution of the data from remote sensing determines its quality.

Spatial Resolution

The size of the ground area that a sensor "sees" at any given moment, or more precisely, each time a signal is collected. It is the smallest separation between two objects that a sensor can clearly register ability to recognize nearby little objects in a picture. Higher the spatial resolution, the smaller the ground resolution cell – the higher the resolving power of the system. By definition, spatial resolution is the mallest angular or linear separation between two objects that can be resolved by sensor which is determined by Instantaneous field of view (IFOV). The resolutions of today's satellite systems vary from a few centimeters (for example military usage) to kilometers.

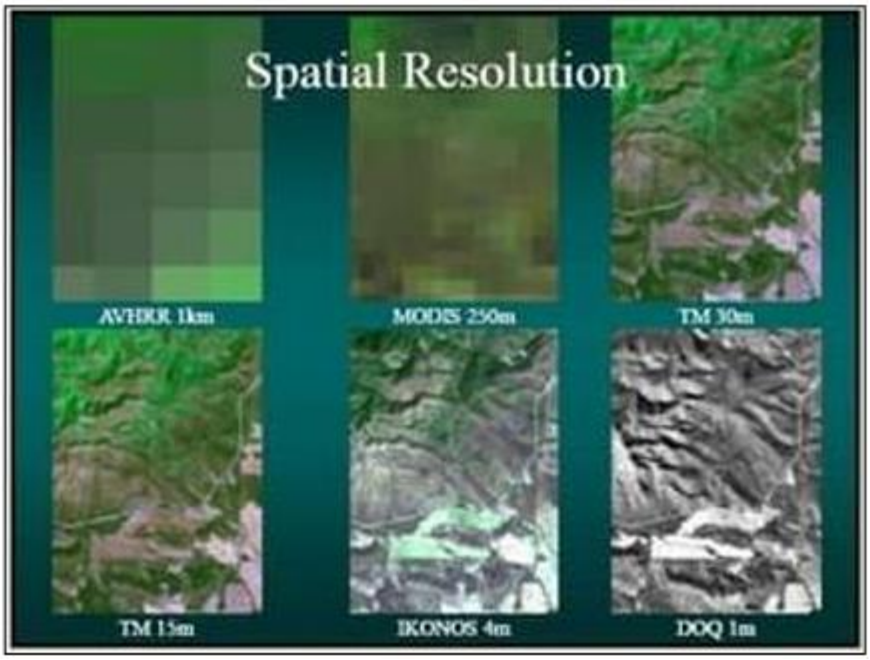

Fig: Spatial Resolution

Spectral Resolution

The capacity to break down spectral features and bands into their individual components is known as spectral resolution. The level of spectral resolution needed by the analyst or researcher will depend on the application in question. It is the accuracy with which slight variations in the wavelength can be recorded. The finer the spectral resolution, the narrower the wavelength range for a particular channel or band. Different features in an image can be identified by comparing their wavelength responses. Broad classes such as water body can be identified using broad wavelength (visible and IR range), whereas more specific classes would require finer wavelength range to identify them such as type of rock. Thus, spectral resolution is the ability of the sensor to separate fine wavelength intervals. While hyperspectral imaging has hundreds or thousands of (narrower) bands (i.e., better spectral resolution), multispectral imagery often refers to 3 to 10 bands.

A single broad band known as panchromatic captures a diverse range of wavelengths.

- Multispectral Sensors – MODIS – moderate spectral resolution
- Hyperspectral Sensors – OMI, AIRS – High spectral resolution

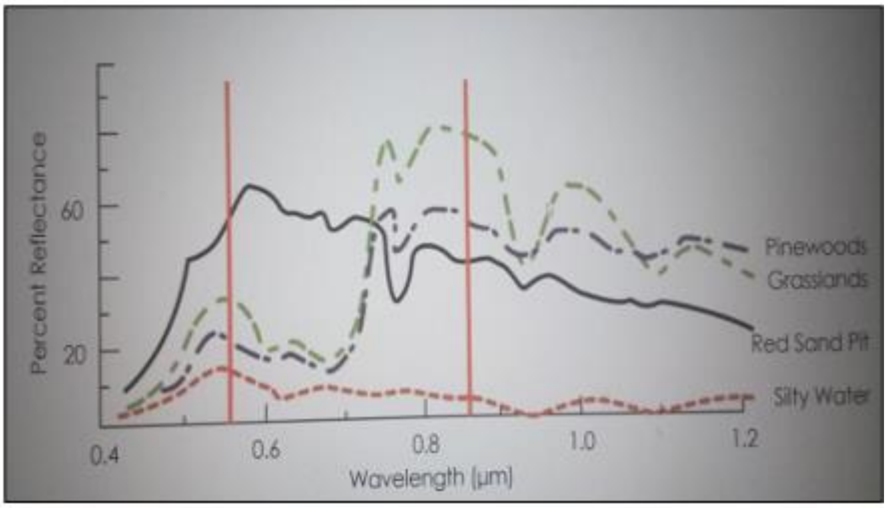

Fig: Spectral Resolution of Different Objects (Indian Institute of Science)

Radiometric Resolution

It is the ability of the sensor to detect the slight variation in the EMR received. Since total EMR received is directly proportional to spatial resolution, there is an inverse relationship between spatial and radiometric resolution – low spatial resolution (large ground area) means more total energy received, so slight variations in EMR can be detected, this results in a high signal to noise ratio – conversely, if spatial resolution is high (small ground area) less total energy is received, slight variations are more difficult to detect, so lower signal to noise ratio, poorer radiometric resolution. Radiometric resolution is normally indicated by the number of quantization levels used to measure reflectance also called DN values for digital numbers. It is determined by bit format of data. It specifies how well the differences in brightness in an image can be perceived; this is measured through the number of the grey value levels. The more sensitive the sensor - the higher the radiometric resolution. If radiometric precision is high, an image will be sharp.

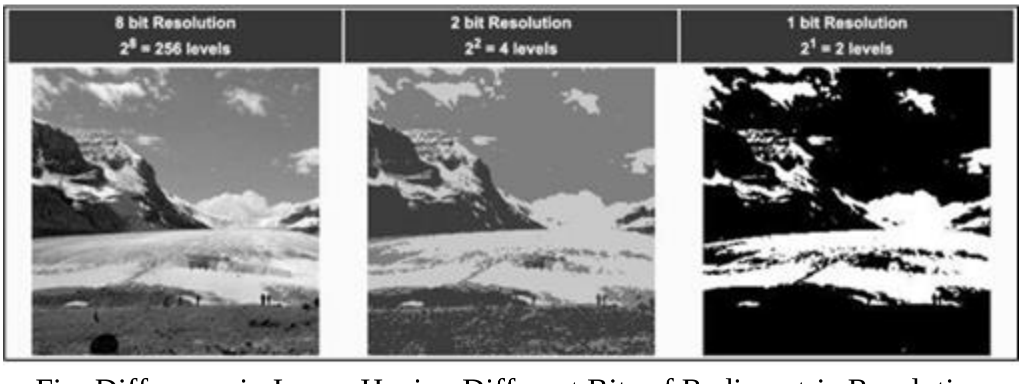

Fig: Difference in Image Having Different Bits of Radiometric Resolution

Temporal Resolution

The frequency with which a remote sensing platform can cover a region is referred to as temporal resolution. While regular orbiting satellites can only offer data once they pass over a region, geo-stationary satellites can provide continuous sensing. In order to supply data for applications requiring more frequent sensing, remote sensing data from cameras placed on aircraft is frequently used. The data from a planned remotely sensed data system may be tampered with by cloud cover. The highest frequent temporal resolution can be obtained via remote sensors placed in fields or attached to agricultural machinery. It is determined by orbital characteristics and swath width (the larger the swath, the higher the temporal resolution)

Global coverage of various satellites is.

- MODIS – 1-2 days
- OMI – 1 day
- MISR – 6-8 days
- VIIRS – 1 day
- Geostationary – 30 sec – 1 hr.

It is very difficult to obtain all resolution at higher levels at the same time.

Advantages

- Allows coverage of very large areas which enables regional surveys on a variety of themes and identification of extremely large features.
- Allows Repetitive coverage which comes in handy when collecting data on dynamic themes such as water, agricultural fields and so on.
- Allows for easy collection of data over a variety of scales and resolutions.
- A single image captured through remote sensing can be analyzed and interpreted for use in various applications and purposes. There is no limitation on the extent of information that can be gathered from a single remotely sensed image.
- Remotely sensed data can easily be processed and analyzed fast using a computer and the data utilized for various purposes.
- Remote sensing is Unobstructed especially if the sensor is passively recording the electromagnetic energy reflected from or emitted by the phenomena of interest. This means that passive remote sensing does not disturb the object or the area of interest.
- Data collected through remote sensing is analyzed at the laboratory which minimizes the work that needs to be done on the field.
- Remote sensing allows for map revision at a small to medium scale which makes it a bit cheaper and faster.
- It is easier to locate floods or forest fire that has spread over a large region which makes it easier to plan a rescue mission easily and fast.
- Remote sensing is a relatively cheap and constructive method reconstructing a base map in the absence of detailed land survey methods.

Disadvantages

- Remote sensing is a fairly expensive method of analysis especially when measuring or analyzing smaller areas.
- Remote sensing requires a special kind of training to analyze the images. It is therefore expensive in the long run to use remote sensing technology since extra training must be accorded to the users of the technology.
- It is expensive to analyze repetitive photographs if there is need to analyze different aspects of the photography features.
- It is humans who select what sensor needs to be used to collect the data, specify the resolution of the data and calibration of the sensor, select the platform that will carry the sensor and determine when the data will be collected. Because of this, it is easier to introduce human error in this kind of analysis.
- Powerful active remote sensing systems such as radars that emit their own electromagnetic radiation can be intrusive and affect the phenomenon being investigated.
- The instruments used in remote sensing may sometimes be un-calibrated which may lead to un-calibrated remote sensing data.
- The image being analyzed may sometimes be interfered by other phenomena that are not being measured and this should also be accounted for during analysis.
- Remote sensing technology is sometimes oversold to the point where it feels like it is a panacea that will provide all the solution and information for conducting physical, biological or scientific research.
- The information provided by remote sensing data may not be complete and may be temporary.
- Sometimes large-scale engineering maps cannot be prepared from satellite data which makes remote sensing data collection incomplete.

Application

- **In Agriculture:** Crop type classification, Crop condition assessment, Crop yield estimation, Mapping of soil characteristics, Mapping of soil management practices and so on.
- **Forestry:** Forest cover, Type of forest, Vegetation density, Deforestation , Forest fires , Biomass estimation.
- **Geology:** Bedrock mapping, Lithological mapping, Structural mapping, Mineral exploration, Hydrocarbon exploration, Environmental geology,etc.
- **Hydrology:** Wetlands mapping and monitoring, Soil moisture estimation, Measuring snow thickness, etc.

- **Sea Ice:** Ice concentration, Iceberg detection and tracking and so on.
- **Fisheries:** Site suitability analysis, Water quality mapping, Habitat suitability assessment

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Geographic Information System: Overview and Components

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Introduction

Geographical Information System (GIS) is a technology that provides the means to collect and use geographic data to assist in the development of Agriculture. A digital map is generally of much greater value than the same map printed on a paper as the digital version can be combined with other sources of data for analyzing information with a graphical presentation. The GIS software makes it possible to synthesize large amounts of different data, combining different layers of information to manage and retrieve the data in a more useful manner. GIS provides a powerful means for agricultural scientists to better service to the farmers and farming community in answering their query and helping in a better decision making to implement planning activities for the development of agriculture.

Overview of GIS

A Geographical Information System (GIS) is a system for capturing, storing, analyzing and managing data and associated attributes, which are spatially referenced to the Earth. The geographical information system is also called as a geographic information system or geospatial information system. It is an information system capable of integrating, storing, editing, analyzing, sharing, and displaying geographically referenced information. In a more generic sense, GIS is a software tool that allows users to create interactive queries, analyze the spatial information, edit data, maps, and present the results of all these operations. GIS technology is becoming essential tool to combine various maps and remote sensing information to generate various models, which are used in real time environment. Geographical information system is the science utilizing the geographic concepts, applications and systems.

Geographical Information System can be used for scientific investigations, resource management, asset management, environmental impact assessment, urban planning, cartography, criminology, history, sales, marketing, and logistics. For example, agricultural planners might use geographical data to decide on the best locations for a location specific crop planning, by combining data on soils, topography, and rainfall to determine the size and location of biologically suitable areas. The final output could include overlays with land ownership, transport, infrastructure, labour availability, and distance to market centers.

History of GIS development

The idea of portraying different layers of data on a series of base maps, and relating things geographically, has been around much older than computers invention. Thousands years ago, the early man used to draw pictures of the animals they hunted on the walls of caves. These animal drawings are track lines and tallies thought to depict migration routes. While simplistic in comparison to modern technologies, these early records mimic the two-element structure of modern geographic information systems, an image associated with attribute information.

Possibly the earliest use of the geographic method, in 1854 John Snow depicted a cholera outbreak in London using points to represent the locations of some individual cases. His study of the distribution of cholera led to the source of the disease, a contaminated water pump within the heart of the cholera outbreak. While the basic elements of topology and theme existed previously in cartography, the John Snow map was unique, using cartographic methods, not only to depict but also to analyze, clusters of geographically dependent phenomena for the first time.

The early 20th century saw the development of "photo lithography" where maps were separated into layers. Computer hardware development spurred by nuclear weapon research led to general-purpose computer "mapping" applications by the early 1960s. In the year 1962, the world's first true operational GIS was developed by the federal Department of Forestry and Rural Development in Ottawa, Canada by Dr. Roger Tomlinson. It was called the "Canada Geographic Information System" (CGIS) and was used to store, analyze, and manipulate data collected for the Canada Land Inventory (CLI). It is an initiative to determine the land capability for rural Canada by mapping information about soils, agriculture, recreation, wildlife, forestry, and land use at a scale of 1:50,000.

CGIS was the world's first "system" and was an improvement over "mapping" applications as it provided capabilities for overlay, measurement, and digitizing or scanning. It supported a national coordinate system that spanned the continent, coded lines as "arcs" having a true embedded topology, and it stored the attribute and location specific information in a separate files. Dr. Tomlinson is known as the "father of GIS," for his use of overlays in promoting the spatial analysis of convergent geographic data.

In 1964, Howard T Fisher formed the Laboratory for Computer Graphics and Spatial Analysis at the Harvard Graduate School of Design, where a number of important theoretical concepts in spatial data handling were developed. This lab had major influence on the development of GIS until early 1980s. Many pioneers of newer GIS "grew up" at the Harvard lab and had distributed seminal software code and systems, such as 'SYMAP', 'GRID', and 'ODYSSEY'.

By the early 1980s, M&S Computing (later Intergraph), Environmental Systems Research Institute (ESRI) and CARIS emerged as commercial vendors of GIS software, successfully incorporating many of the CGIS features, combining the first generation approach to separation of spatial and attribute information with a second generation approach to organizing attribute data into database structures. More functions for user interaction were developed mainly in a graphical way by a user friendly interface (Graphical User Interface), which gave to the user the ability to sort, select, extract, reclassify, reproject and display data on the basis of complex geographical, topological and statistical criteria. During the same time, the development of a public domain GIS begun by the U.S. Army Corp of Engineering Research Laboratory (USA-CERL) in Champaign, Illinois, a branch of the U.S. Army Corps of Engineers to meet the need of the United States military for software for land management and environmental planning.

In the years 1980s and 1990s industry growth were spurred on by the growing use of GIS on Unix workstations and the personal computers. By the end of the 20th century, the rapid growth in various systems had been consolidated and standardized on relatively few platforms and users were beginning to export the concept of viewing GIS data over the Internet, requiring uniform data format and transfer standards. More recently, there is a growing number of free, open source GIS packages, which run on a range of operating systems and can be customized to perform specific tasks. As computing power increased and hardware prices slashed down, the GIS became a viable technology for state development planning. It has become a real Management Information System (MIS), and thus able to support decision making processes.

Components of GIS

GIS enables the user to input, manage, manipulate, analyze, and display geographically referenced data using a computerized system. To perform various operations with GIS, the components of GIS such as software, hardware, data, people and methods are essential.

1. Software

GIS software provides the functions and tools needed to store, analyze, and display geographic information. Key software components are (a) a database management system (DBMS) (b) tools for the input and manipulation of geographic information (c) tools that support geographic query, analysis, and visualization (d) a graphical user interface (GUI) for easy access to tools. GIS software are either commercial software or software developed on Open Source domain, which are available for free. However, the commercial software is copyright protected, can be expensive and is available in terms number of licensees.

Currently available commercial GIS software includes ArcGIS, ARCPRO, Intergraph, MapInfo, Gram++ etc. Out of these ArcPRO is the most popular software package. And, the open source software are QGIS, DIVA GIS, AMS/MARS etc.

2. Hardware

Hardware is the computer on which a GIS operates. Today, GIS runs on a wide range of hardware types, from centralized computer servers to desktop computers used in stand-alone or networked configurations

3. Data

The most important component of a GIS is the data. Geographic data or Spatial data and related tabular data can be collected in-house or bought from a commercial data provider. Spatial data can be in the form of a map/remotely-sensed data such as satellite imagery and aerial photography. These data forms must be properly geo referenced (latitude/longitude). Tabular data can be in the form attribute data that is in some way related to spatial data. Most

GIS software comes with inbuilt Database Management Systems (DBMS) to create and maintain a database to help organize and manage data.

4. Users

GIS technology is of limited value without the users who manage the system and to develop plans for applying it. GIS users range from technical specialists who design and maintain the system to those who use it to help them do their everyday work.

These users are largely interested in the results of the analyses and may have no interest or knowledge of the methods of analysis. The user-friendly interface of the GIS software allows the nontechnical users to have easy access to GIS analytical capabilities without needing to know detailed software commands. A simple User Interface (UI) can consist of menus and pull-down graphic windows so that the user can perform required analysis with a few key presses without needing to learn specific commands in detail.

5. Methods

A successful GIS operates according to a well-designed plan and business rules, which are the models and operating practices unique to each organization.

Functions of GIS

General-purpose GIS software performs six major tasks such as input, manipulation, management, query and analysis, Visualization.

1. Input

The important input data for any GIS is digitized maps, images, spatial data and tabular data. The tabular data is generally typed on a computer using relational database management system software. Before geographic data can be used in a GIS it must be converted into a suitable digital format. The DBMS system can generate various objects such as index generation on data items, to speed up the information retrieval by a query. Maps can be digitized using a vector format in which the actual map points, lines, and polygons are stored as coordinates. Data can also be input in a raster format in which data elements are stored as cells in a grid structure (the technology details are covered in following section).

The process of converting data from paper maps into computer files is called digitizing. Modern GIS technology has the capability to automate this process fully for large projects; smaller jobs may require some manual digitizing. The digitizing process is labour intensive and time-consuming, so it is better to use the data that already exist.Today many types of geographic data already exist in GIS-compatible formats. These data can be obtained from data suppliers and loaded directly into a GIS.

2. Manipulation

GIS can store, maintain, distribute and update spatial data associated text data. The spatial data must be referenced to a geographic coordinate systems (latitude/longitude). The tabular data associated with spatial data can be manipulated with help of data base management software. It is likely that data types required for a particular GIS project will need to be transformed or manipulated in some way to make them compatible with the system. For example, geographic information is available at different scales (scale of 1:100,000; 1:10,000; and 1:50,000). Before these can be overlaid and integrated they must be transformed to the same scale. This could be a temporary transformation for display purposes or a permanent one required for analysis. And, there are many other types of data manipulation that are routinely performed in GIS. These include projection changes, data aggregation, generalization and weeding out unnecessary data.

3. Management

For small GIS projects it may be sufficient to store geographic information as computer files. However, when data volumes become large and the number of users of the data becomes more than a few, it is advised to use a database management system (DBMS) to help store, organize, and manage data. A DBMS is a database management software package to manage the integrated collection of database objects such as tables, indexes, query, and other procedures in a database.

There are many different models of DBMS, but for GIS use, the relational model database management systems will be highly helpful. In the relational model, data are stored conceptually as a collection of tables and each table will have the data attributes related to a common entity. Common fields in different tables are used to link them together with relations. Because of its simple architecture, the relational DBMS software has been used so widely. These are flexible in nature and have been very wide deployed in applications both within and without GIS**.**

4. Query

The stored information either spatial data or associated tabular data can be retrieved with the help of Structured Query Language (SQL). Depending on the type of user interface, data can be queried using the SQL or a menu driven system can be used to retrieve map data. For example, you can begin to ask questions such as:

- Where are all the soils are suitable for sunflower crop?
- What is the dominant soil type for Paddy?
- What is the groundwater available position in a village/block/district?

Both simple and sophisticated queries utilizing more than one data layer can provide timely information to officers, analysts to have overall knowledge about situation and can take a more informed decision.

5. Analysis

GIS systems really come into their own when they are used to analyze geographic data. The processes of geographic analysis often called spatial analysis or geo-processing uses the geographic properties of features to look for patterns and trends, and to undertake "what if" scenarios. Modern GIS have many powerful analytical tools to analyse the data.

a. Overlay Analysis

The integration of different data layers involves a process called overlay. At its simplest, this could be a visual operation, but analytical operations require one or more data layers to be joined physically. This overlay, or spatial join, can integrate data on soils, slope, and vegetation, or land ownership. For example, data layers for soil and land use can be combined resulting in a new map which contains both soil and land use information. This will be helpful to understand the different behaviour of the situation on different parameters.

b. Proximity Analysis

GIS software can also support buffer generation that involves the creation of new polygons from points, lines, and polygon features stored in the database. For example, to know answer to questions like; How much area covered within 1 km of water canal? What is area covered under different crops? And, for watershed projects, where is the boundary or delineation of watershed, slope, water channels, different types water harvesting structures are required, etc.

6. Visualization

GIS can provide hardcopy maps, statistical summaries, modeling solutions and graphical display of maps for both spatial and tabular data. For many types of geographic operation the end result is best visualized as a map or graph. Maps are very efficient at storing and communicating geographic information. GIS provides new and exciting tools to extend the art of visualization of output information to the users.

Technology used in GIS

Data creation

Modern GIS technologies use digital information, for which various digitized data creation methods are used. The most common method of data creation is digitization, where a hard copy map or survey plan is transferred into a digital medium through the use of a computer-aided design program with geo-referencing capabilities. With the wide availability of rectified imagery (both from satellite and aerial sources), heads-up digitizing is becoming the main avenue through which geographic data is extracted. Heads-up digitizing involves the tracing of geographic data directly on top of the aerial imagery instead of through the traditional method of tracing the geographic form on a separate digitizing tablet.

Data representation

GIS data represents real world objects such as roads, land use, elevation with digital data. Real world objects can be divided into two abstractions: discrete objects (a house) and continuous fields (rain fall amount or elevation). There are two broad methods used to store data in a GIS for both abstractions: Raster and Vector.

a. Raster

A raster data type is, in essence, any type of digital image. Anyone who is familiar with digital photography will recognize the pixel as the smallest individual unit of an image. A combination of these pixels will create an image, distinct from the commonly used scalable vector graphics, which are the basis of the vector model. While a digital image is concerned with the output as representation of reality, in a photograph or art transferred to computer, the raster data type will reflect an abstraction of reality. Aerial photos are one commonly used form of raster data, with only one purpose, to display a detailed image on a map or for the purposes of digitization. Other raster data sets will contain information regarding elevation, a DEM (digital Elevation Model), or reflectance of a particular wavelength of light.

Digital elevation model, map, and vector data, Raster data type consists of rows and columns of cells each storing a single value. Raster data can be images (raster images) with each pixel containing a color value. Additional values recorded for each cell may be a discrete value, such as land use, a continuous value, such as temperature, or a null value if no data is available. While a raster cell stores a single value, it can be extended by using raster bands to represent RGB (red, green, blue) colors, colormaps (a mapping between a thematic code and RGB value), or an extended attribute table with one row for each unique cell value. The resolution of the raster data set is its cell width in ground units.

Raster data is stored in various formats; from a standard file-based structure of TIF, JPEG formats to binary large object (BLOB) data stored directly in a relational database management system (RDBMS) similar to other vector-based feature classes. Database storage, when properly indexed, typically allows for quicker retrieval of the raster data but can require storage of millions of significantly sized records.

b. Vector

A simple vector map, using each of the vector elements: points for wells, lines for rivers, and a polygon for the lake. In a GIS, geographical features are often expressed as vectors, by considering those features as geometrical shapes. In the popular ESRI Arc series of programs, these are explicitly called shape files. Different geographical features are best expressed by different types of geometry:

1. Points

Zero-dimensional points are used for geographical features that can best be expressed by a single grid reference; in other words, simple location. For example, the locations of wells, peak elevations, features of interest or trailheads. Points convey the least amount of information of these file types.

2. Lines or polylines

One-dimensional lines or polylines are used for linear features such as rivers, roads, railroads, trails, and topographic lines.

3. Polygons

Two-dimensional polygons are used for geographical features that cover a particular area of the earth's surface. Such features may include lakes, park boundaries, buildings, city boundaries, or land uses. Polygons convey the most amount of information of the file types.

Each of these geometries are linked to a row in a database that describes their attributes. For example, a database that describes lakes may contain a lake's depth, water quality, pollution level. This information can be used to make a map to describe a particular attribute of the dataset. For example, lakes could be coloured depending on level of pollution. Different geometries can also be compared. For example, the GIS could be used to identify all wells (point geometry) that are within 1-mile (1.6 km) of a lake (polygon geometry) that has a high level of pollution.

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Global Positioning System (GPS) Applications in Fisheries Resource mapping

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Introduction

The Global Positioning System (GPS) has revolutionized various sectors, including agriculture, transportation, and environmental monitoring. One of the most significant applications of GPS technology is in the management and sustainable utilization of fishery resources. This chapter explores the diverse applications of GPS in fisheries, highlighting its role in enhancing efficiency, sustainability, and safety in the fishing industry.

GPS Technology: An Overview

GPS is a satellite-based navigation system that provides geolocation and time information to a GPS receiver anywhere on or near the Earth. The system consists of a constellation of at least 24 satellites orbiting the Earth, ground control stations, and GPS receivers. The satellites transmit signals that allow GPS receivers to determine their exact location (latitude, longitude, and altitude) and the precise time.

Working of GPS

1. **Satellite Constellation**: GPS satellites orbit the Earth at an altitude of approximately 20,200 kilometers. Each satellite transmits a unique signal and orbital parameters that allow GPS receivers to decode and compute the precise location of the satellite.
2. **Signal Transmission**: The GPS receiver calculates the distance to each satellite by measuring the time delay between the transmission and reception of the signal. With signals from at least four satellites, the receiver can determine its three-dimensional position (latitude, longitude, and altitude).
3. **Position Calculation**: Using trilateration, the GPS receiver combines the distance measurements from multiple satellites to compute its exact location.

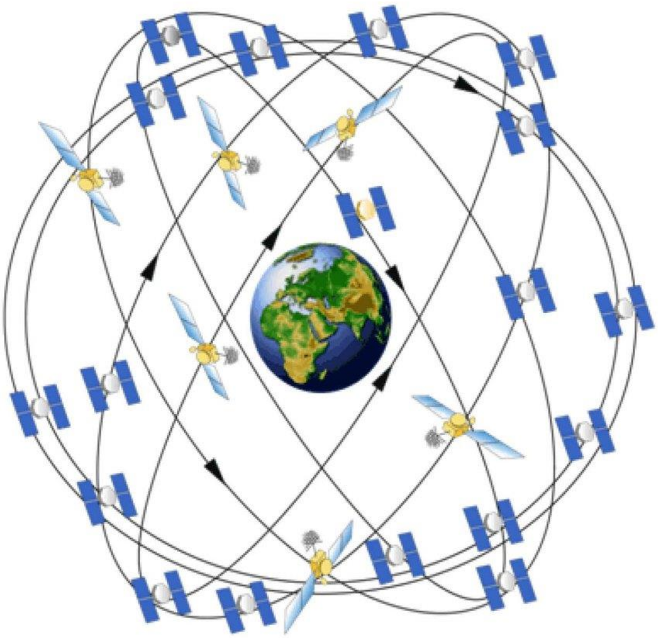

Fig: GPS Satellite Constellation

Applications of GPS in Fisheries

1. Navigation and Fleet Management

One of the primary applications of GPS in fisheries is navigation. Fishing vessels equipped with GPS receivers can accurately determine their position, even in the open sea where landmarks are absent. This capability is crucial for:

- **Route Optimization**: GPS enables fishermen to plot the most efficient routes to fishing grounds, reducing fuel consumption and travel time.
- **Safety**: In case of emergencies, such as engine failure or severe weather, GPS allows for precise location reporting, facilitating rapid rescue operations.
- **Fleet Tracking**: Fisheries management authorities can monitor the movement of fishing vessels in real-time, ensuring compliance with regulations and preventing illegal fishing activity

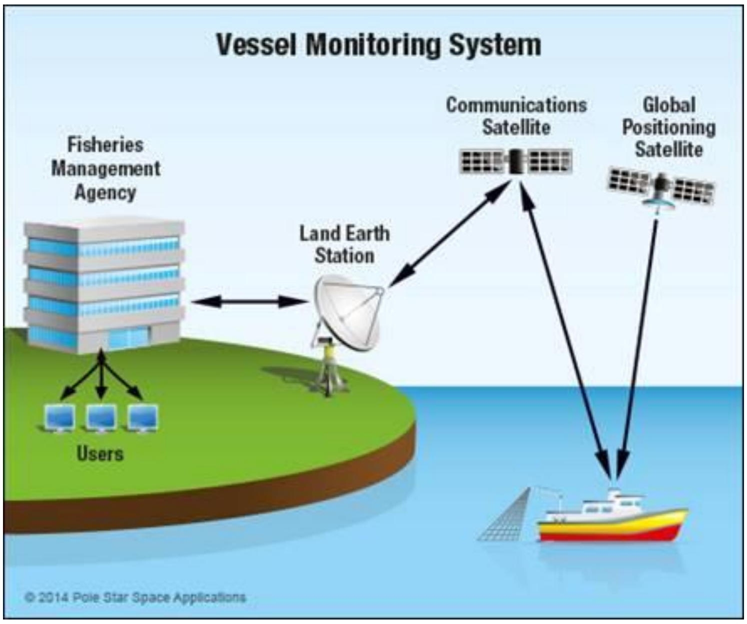

Fig: GPS Navigation System on a Fishing Vessel

2. Fish Stock Assessment and Habitat Mapping

GPS technology is instrumental in fish stock assessment and habitat mapping. By combining GPS data with other technologies such as Geographic Information Systems (GIS) and sonar, researchers can:

- **Map Fishing Grounds**: GPS allows for the precise mapping of fishing grounds, including the location of fish schools, coral reefs, and other underwater features.
- **Monitor Fish Movements**: Acoustic tags equipped with GPS can track the movements of fish, providing valuable data on migration patterns, spawning grounds, and habitat preferences.
- **Assess Stock Levels**: By integrating GPS data with catch records, researchers can estimate fish stock levels and assess the health of fish populations.

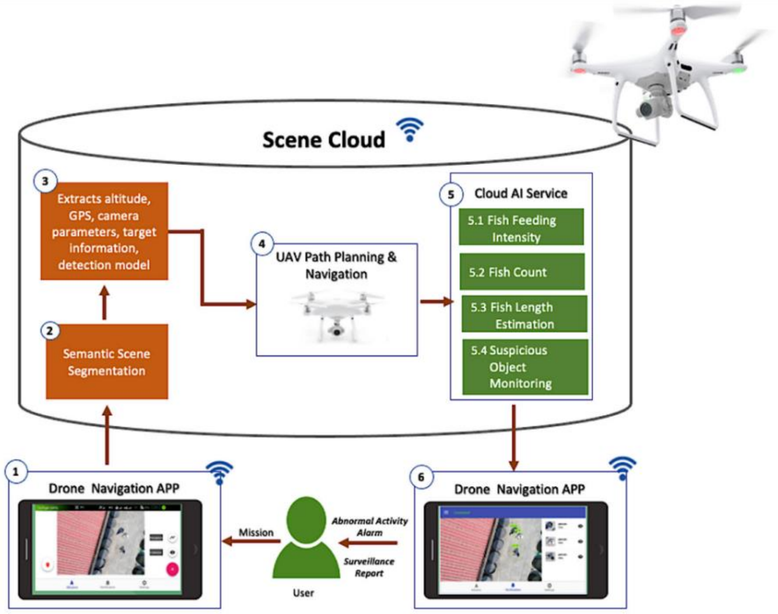

Fig: Fish Stock Assessment Using GPS and Sonar Technology

3. Sustainable Fishing Practices

GPS plays a critical role in promoting sustainable fishing practices. By providing accurate data on fishing activities, GPS helps in:

- **Avoiding Overfishing**: Real-time monitoring of fishing activities allows authorities to enforce catch limits and prevent overfishing in sensitive areas.
- **Reducing Bycatch**: GPS can be used to identify areas with high bycatch rates, enabling fishermen to avoid these zones and reduce unintended catch of non-target species.
- **Marine Protected Areas (MPAs)**: GPS data is used to establish and monitor MPAs, ensuring that these critical habitats are protected from fishing activities.

Fig: GPS-Enabled Sustainable Fishing Practices

4. Aquaculture Management

In aquaculture, GPS technology is used to optimize the location and management of fish farms. Key applications include:

- **Site Selection**: GPS data helps in selecting optimal sites for fish farms, considering factors such as water quality, depth, and proximity to markets.
- **Cage Positioning**: GPS is used to precisely position fish cages, ensuring they are placed in areas with favorable environmental conditions.
- **Environmental Monitoring**: GPS-enabled sensors can monitor water temperature, salinity, and other parameters, providing real-time data for effective farm management.

5. Illegal, Unreported, and Unregulated (IUU) Fishing Monitoring

IUU fishing is a significant threat to global fish stocks. GPS technology is a powerful tool in combating IUU fishing by:

- **Vessel Monitoring Systems (VMS)**: GPS-based VMS allows authorities to track the location and activities of fishing vessels, ensuring compliance with fishing regulations.
- **Electronic Reporting**: GPS data can be integrated with electronic reporting systems, providing accurate and timely information on catch volumes and fishing locations.
- **Enforcement**: GPS data can be used as evidence in legal proceedings against vessels engaged in IUU fishing.

Challenges and Future Directions

While GPS technology has transformed the fishing industry, several challenges remain:

- **Cost**: The initial cost of GPS equipment and ongoing maintenance can be prohibitive for small-scale fishermen.
- **Data Accuracy**: Environmental factors such as atmospheric conditions and signal interference can affect GPS accuracy.
- **Data Management**: The large volume of data generated by GPS systems requires robust data management and analysis tools.

Future advancements in GPS technology, such as the integration of Artificial Intelligence (AI) and Machine Learning (ML), are expected to further enhance its applications in fisheries. These technologies could enable predictive analytics, improving decision-making in fish stock management and sustainable fishing practices

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Geographic Information Systems: Software and System Requirements

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Introduction

GIS (Geographic Information System) software is a specialized tool that allows users to capture, store, analyze, and visualize spatial or geographic data. It integrates various data types, including maps, satellite imagery, and tabular information, to provide insights into spatial relationships, patterns, and trends.

GIS software is used in diverse fields such as urban planning, environmental management, transportation, agriculture, disaster management, and business intelligence.

Types of GIS Software

GIS software can be categorized into several types based on functionality and application:

- **Desktop GIS**
  - Standalone applications installed on a local computer.
  - Provide robust spatial analysis, data processing, and visualization tools.
  - Examples: ArcGIS Pro, QGIS, MapInfo Pro, GRASS GIS.
- **Web GIS**
  - Cloud-based GIS solutions accessible via web browsers.
  - Support collaborative mapping, real-time data sharing, and online geospatial analysis.
  - Examples: ArcGIS Online, Google Earth Engine, Mapbox.
- **Server GIS**
  - Enterprise-level GIS that allows multiple users to access and analyze spatial data remotely.
  - Used for large-scale applications, integrating GIS with databases and web services.
  - Examples: ArcGIS Server, GeoServer, MapServer.
- **Mobile GIS**
  - GIS applications designed for field data collection and analysis using smartphones or tablets.
  - Used in agriculture, forestry, and infrastructure monitoring.
  - Examples: ArcGIS Field Maps, QField, Locus Map.
- **Remote Sensing GIS**
  - Specialized GIS software used for analyzing satellite imagery and aerial photography.

  - Supports raster data processing, land use classification, and environmental monitoring.
  - Examples: ERDAS IMAGINE, ENVI, Google Earth Engine.

Detailed Description of Existing GIS Software

Here's a comprehensive list of GIS software, including their features, system requirements, and cost:

1. ArcGIS Pro (Commercial)

- **Developer:** Esri
- **Description:** ArcGIS Pro is a leading GIS desktop software that offers advanced spatial analysis, 2D/3D visualization, and geoprocessing tools.
- **Key Features:**
  - 3D visualization with ArcGIS Scene
  - AI-powered spatial analysis
  - Integration with ArcGIS Online and Server
- **System Requirements:**
  - OS: Windows 10 or later
  - Processor: 2.2 GHz+
  - RAM: 8GB (16GB recommended)
  - Storage: 32GB free space
- **Cost:** Subscription-based, starting at ~$100/year for personal use, higher for enterprise plans.

2. QGIS (Open Source)

- **Developer:** Open Source Geospatial Foundation (OSGeo)
- **Description:** QGIS is a free, open-source GIS software offering extensive features for spatial analysis and data visualization.
- **Key Features:**
  - Supports multiple GIS data formats
  - Plugin architecture for customization
  - Integration with Python and R for geospatial scripting
- **System Requirements:**
  - OS: Windows, macOS, Linux

- Processor: 1 GHz+
- RAM: 4GB (8GB recommended)
- Storage: 2GB free space

- **Cost:** Free

3. MapInfo Pro (Commercial)

- **Developer:** Precisely (formerly Pitney Bowes)
- **Description:** MapInfo Pro is a powerful desktop GIS solution used in business analytics and urban planning.
- **Key Features:**
  - User-friendly interface
  - Advanced geospatial analytics
  - Spatial SQL support
- **System Requirements:**
  - OS: Windows 10 or later
  - Processor: 2 GHz+
  - RAM: 4GB (8GB recommended)
  - Storage: 2GB free space
- **Cost:** Subscription-based, pricing available upon request.

4. Maptitude (Commercial)

- **Developer:** Caliper Corporation
- **Description:** Maptitude is a business-focused GIS software designed for market analysis and spatial data visualization.
- **Key Features:**
  - Built-in demographic and business datasets
  - Route optimization
  - Geocoding and spatial analytics
- **System Requirements:**
  - OS: Windows 10 or later
  - Processor: 1 GHz+
  - RAM: 4GB (8GB recommended)

  - Storage: 10GB free space
- **Cost:** One-time purchase, ~$695.

5. GRASS GIS (Open Source)

- **Developer:** GRASS Development Team
- **Description:** GRASS GIS is a powerful open-source GIS application widely used in environmental modeling and remote sensing.
- **Key Features:**
  - Advanced raster and vector processing
  - Python and R integration
  - 3D terrain analysis
- **System Requirements:**
  - OS: Windows, macOS, Linux
  - Processor: 1 GHz+
  - RAM: 4GB (8GB recommended)
  - Storage: 2GB free space
- **Cost:** Free

6. Google Earth Pro (Free)

- **Developer:** Google
- **Description:** Google Earth Pro is a 3D mapping application with satellite imagery, terrain data, and geospatial measurements.
- **Key Features:**
  - Historical satellite imagery
  - 3D globe visualization
  - Basic GIS tools for area measurement and overlays
- **System Requirements:**
  - OS: Windows, macOS
  - Processor: 1 GHz+
  - RAM: 4GB+
  - Storage: 2GB free space

- **Cost:** Free

7. ArcGIS Online (Commercial Web GIS)

- **Developer:** Esri
- **Description:** A cloud-based GIS for creating, sharing, and analyzing spatial data in a web environment.
- **Key Features:**
  - Cloud-based map hosting
  - Collaboration tools
  - Integration with mobile and desktop GIS
- **Cost:** Subscription-based, starting at ~$100 per year.

8. Google Earth Engine (Web-based Remote Sensing GIS)

- **Developer:** Google
- **Description:** A cloud-based platform for analyzing large-scale geospatial data, including satellite imagery and environmental datasets.
- **Key Features:**
  - Access to global satellite imagery archives
  - Machine learning integration for geospatial analysis
  - API for Python and JavaScript
- **Cost:** Free for research and educational purposes; pricing for enterprise use varies.

9. ENVI (Commercial Remote Sensing GIS)

- **Developer:** L3Harris Geospatial
- **Description:** ENVI specializes in remote sensing data processing, used extensively in land use analysis and environmental monitoring.
- **Key Features:**
  - Hyperspectral and multispectral image processing
  - AI-based geospatial analysis
  - SAR (Synthetic Aperture Radar) processing
- **System Requirements:**
  - OS: Windows 10 or later
  - RAM: 8GB+

    - Storage: 20GB+
- **Cost:** Custom pricing based on licensing model.

10. GeoServer (Open-Source Server GIS)

- **Developer:** OSGeo
- **Description:** GeoServer is an open-source platform for publishing geospatial data via web services.
- **Key Features:**
    - Supports OGC standards (WMS, WFS, WCS)
    - Integration with PostGIS database
    - Web mapping API support
- **System Requirements:**
    - OS: Windows, Linux, macOS
    - RAM: 4GB+
    - Requires Java environment
- **Cost:** Free

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Satellite Data: Types and Repositories

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Introduction

Satellite data refers to information collected by artificial satellites orbiting Earth. These satellites capture images, atmospheric readings, and geospatial data using advanced sensors such as optical cameras, radar, and infrared detectors. The data can be in different formats, including:

- **Optical imagery** (e.g., Landsat, Sentinel-2)
- **Radar (SAR) data** (e.g., Sentinel-1, RADARSAT)
- **Thermal data** (e.g., MODIS, ASTER)
- **Elevation data** (e.g., SRTM, LiDAR)
- **Atmospheric data** (e.g., Sentinel-5P, GOES)

Satellite data comes in different formats based on the type of sensor and the nature of the data. The most common formats include optical imagery, radar (SAR) data, thermal data, elevation data, and atmospheric data. Below is a detailed explanation of each category, including key satellite missions, data formats, and use cases.

1. Optical Imagery (e.g., Landsat, Sentinel-2)

Optical imagery is satellite data captured in the **visible and infrared spectrum**. These images resemble photographs taken from space and are often used for land cover mapping, vegetation monitoring, and urban planning.

Key Satellites

- Landsat Series (Landsat 1-9) – Operated by NASA/USGS, provides 30m resolution multispectral data.
- Sentinel-2 (A & B) – Operated by ESA, provides 10m–60m resolution multispectral data.
- MODIS (Moderate Resolution Imaging Spectroradiometer) – Provides 250m–1km resolution imagery for global environmental monitoring.
- SPOT (Satellite Pour l'Observation de la Terre) – High-resolution optical imagery (1.5m to 6m).
- WorldView & QuickBird (Commercial) – Ultra-high-resolution (30cm) optical imagery for detailed analysis.

Data Formats

- GeoTIFF (.tif) – Most common format, georeferenced for GIS applications.
- HDF (Hierarchical Data Format) – Used for MODIS and ASTER data, supports large datasets.
- NetCDF (Network Common Data Form) – Used for climate and atmospheric studies.
- JPEG2000 (.jp2) – Used in Sentinel-2 data, provides efficient compression.

Applications

- Land use & land cover (LULC) classification
- Forest and vegetation monitoring
- Urban expansion and infrastructure planning
- Agriculture and crop health assessment
- Water body mapping

2. Radar (SAR) Data (e.g., Sentinel-1, RADARSAT)

Synthetic Aperture Radar (SAR) data uses microwave signals to capture images of the Earth's surface. Unlike optical sensors, SAR can penetrate clouds, operate in darkness, and detect surface changes.

Key Satellites

- Sentinel-1 (A & B) – European SAR satellites with C-band radar (5m–20m resolution).
- RADARSAT (1, 2, and RCM) – Canadian SAR satellites for flood, ice, and disaster monitoring.
- ALOS PALSAR (Advanced Land Observing Satellite – Phased Array L-band SAR) – High-resolution radar data.
- TerraSAR-X & TanDEM-X – High-resolution commercial radar satellites (1m–3m).

Data Formats

- GeoTIFF (.tif) – Standard format for SAR images.
- GRD (Ground Range Detected) – Pre-processed SAR images with radiometric and geometric corrections.
- SLC (Single Look Complex) – Contains both amplitude and phase information, used for interferometry.
- HDF5 (.h5) – Used in advanced radar datasets.

Applications

- Flood mapping and disaster response
- Landslide and earthquake deformation analysis
- Deforestation monitoring
- Infrastructure change detection
- Glacier and sea ice monitoring

3. Thermal Data (e.g., MODIS, ASTER)

Thermal sensors capture infrared radiation emitted from the Earth's surface. This data is used to measure land and sea surface temperatures, detect wildfires, and analyze urban heat islands.

Key Satellites

- MODIS (Terra & Aqua) – Provides 1km resolution global thermal imagery.
- ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) – Offers 90m resolution thermal data.
- Landsat 8-9 (TIRS – Thermal Infrared Sensor) – Measures surface temperature at 100m resolution.
- GOES (Geostationary Operational Environmental Satellite) – Provides real-time weather and thermal infrared data.

Data Formats

- **GeoTIFF (.tif)** – Used for temperature anomaly analysis.
- **HDF (.hdf)** – Supports multi-band storage (e.g., MODIS data).
- **NetCDF (.nc)** – Used for atmospheric and oceanic temperature data.

Applications

- Wildfire detection and monitoring
- Urban heat island analysis
- Sea surface temperature monitoring
- Geothermal activity and volcano monitoring
- Drought assessment

4. Elevation Data (e.g., SRTM, LiDAR)

Elevation data provides digital elevation models (DEMs) representing Earth's surface topography. It is critical for hydrology, land planning, and infrastructure development.

Key Datasets & Satellites

- SRTM (Shuttle Radar Topography Mission) – Provides 30m and 90m resolution DEMs.
- LiDAR (Light Detection and Ranging) – Airborne sensors providing high-resolution 1m–10m elevation data.
- ALOS PALSAR DEM – Provides global 12.5m resolution elevation models.
- TanDEM-X DEM – High-resolution global elevation model (12m).

Data Formats

- GeoTIFF (.tif) – Standard format for elevation models.
- ASCII Grid (.asc) – Text-based format for DEMs.
- LAS (.las) & LAZ (.laz) – Used for LiDAR point cloud data.
- DTED (Digital Terrain Elevation Data) – Military-grade elevation format.

Applications

- Flood risk modeling and hydrology
- 3D terrain visualization and mapping
- Landslide and erosion studies
- Infrastructure and urban planning

5. Atmospheric Data (e.g., Sentinel-5P, GOES)

Atmospheric data measures air quality, greenhouse gases, and meteorological parameters. It is crucial for climate science, pollution monitoring, and weather forecasting.

Key Satellites

- Sentinel-5P (TROPOMI Instrument) – Measures air pollution (CO_2, NO_2, O_3, SO_2, aerosols).
- GOES (Geostationary Operational Environmental Satellite) – Provides real-time meteorological and cloud cover data.
- MODIS (Terra & Aqua) – Monitors atmospheric aerosols, dust, and cloud properties.
- OMI (Ozone Monitoring Instrument) – Tracks ozone layer depletion and UV radiation.

Data Formats

- NetCDF (.nc) – Standard for atmospheric and climate data.
- HDF5 (.h5) – Used for Sentinel-5P and MODIS datasets.

- BUFR (Binary Universal Form for the Representation of meteorological data) – Used for weather models.

Applications

- Air quality and pollution monitoring
- Ozone layer depletion analysis
- Greenhouse gas tracking (CO_2, CH_4, NO_2)
- Weather forecasting and climate modeling
- Dust storm and wildfire smoke detection

Summary

Data Type	Key Satellites	Best Format	Applications
Optical	Landsat, Sentinel-2	GeoTIFF, HDF	Land cover, urban planning
Radar (SAR)	Sentinel-1, RADARSAT	SLC, GRD	Flood mapping, surface deformation
Thermal	MODIS, ASTER	HDF, GeoTIFF	Wildfires, sea surface temperature
Elevation	SRTM, LiDAR	GeoTIFF, LAS	Flood modeling, 3D mapping
Atmospheric	Sentinel-5P, GOES	NetCDF, HDF	Air pollution, weather forecasting

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Platforms for downloading satellite data

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Introduction

There are numerous platforms available for downloading satellite data, offering different types of imagery, spatial resolutions, temporal coverage, and data processing tools. Below is a comprehensive list of the best free and commercial satellite data download resources, along with their features.

Free Satellite Data Download Resources

1. USGS Earth Explorer

Website: https://earthexplorer.usgs.gov/

Features:

- Provides access to Landsat (1-9), Sentinel-2, MODIS, ASTER, and other datasets.
- Allows search based on date, region, and cloud cover.
- Offers multiple file formats (GeoTIFF, HDF, NetCDF).
- Supports bulk downloading via scripts or manual selection.

Best For:

- Researchers and analysts needing medium-resolution imagery (10m–30m).
- Environmental monitoring, land use/land cover studies, and disaster response.

2. Copernicus Open Access Hub (Sentinel Data)

Website: https://scihub.copernicus.eu/

Features:

- Provides Sentinel-1 (SAR), Sentinel-2 (Optical), Sentinel-3 (Ocean and Land), and Sentinel-5P (Atmosphere) data.
- Global coverage with high temporal resolution (revisit times of 5–10 days).
- Free and open access for research and operational use.
- Multi-spectral and Synthetic Aperture Radar (SAR) capabilities.

Best For:

- Vegetation monitoring, flood detection, land classification, and atmospheric studies.

3. NASA Earthdata Search

Website: https://search.earthdata.nasa.gov/

Features:

- Offers MODIS, VIIRS, ASTER, GEDI, SMAP, and ICESat-2 data.
- Provides on-demand processing and subsetting services.
- Data available in multiple formats including NetCDF, HDF, and GeoTIFF.
- Search and filter by parameters like time range, location, and dataset type.

Best For:

- Climate studies, oceanography, and atmospheric research.

4. Google Earth Engine (GEE)

Website: https://earthengine.google.com/

Features:

- Cloud-based platform offering access to petabytes of satellite data.
- Includes datasets from Landsat, Sentinel, MODIS, and climate models.
- Supports real-time geospatial analysis with JavaScript and Python APIs.
- No need for downloads; computations run in the cloud.

Best For:

- Large-scale data analysis, machine learning in remote sensing, and real-time environmental monitoring.

5. NOAA CLASS (National Oceanic and Atmospheric Administration)

Website: https://www.class.noaa.gov/

Features:

- Provides meteorological and oceanographic data from NOAA satellites (GOES, JPSS, POES, AVHRR).
- High temporal resolution satellite data for weather monitoring.
- Data available in NetCDF and HDF formats.

Best For:

- Weather forecasting, climate change analysis, and disaster response.

6. Alaska Satellite Facility (ASF DAAC - SAR Data)

Website: https://search.asf.alaska.edu/

Features:

- Specializes in Synthetic Aperture Radar (SAR) imagery from Sentinel-1, ALOS PALSAR, UAVSAR, and RADARSAT.
- Offers high-resolution radar data for all-weather, day/night imaging.
- Provides access to cloud computing via the HyP3 platform for SAR data processing.

Best For:

- Glacier movement analysis, flood mapping, and deforestation monitoring.

7. Global Land Cover Facility (GLCF)

Website: https://glcf.umd.edu/

Features:

- Free access to Landsat, MODIS, and AVHRR land cover datasets.
- Supports time-series land use/land cover analysis.
- Offers pre-processed vegetation indices and climate datasets.

Best For:

- Land cover classification, deforestation studies, and ecological monitoring.

8. LP DAAC (Land Processes Distributed Active Archive Center)

Website: https://lpdaac.usgs.gov/

Features:

- Offers ASTER, MODIS, VIIRS, GEDI, and SRTM datasets.
- Provides on-the-fly subsetting and reformatting.
- Integrated with NASA's Earthdata Search for easier access.

Best For:

- Land surface temperature, vegetation monitoring, and topographic mapping.

9. Radiant Earth Foundation

Website: https://www.radiant.earth/

Features:

- Open-access geospatial datasets for AI and machine learning applications.
- Provides training datasets for deep learning in remote sensing.

- Supports cloud-native processing.

Best For:

- Machine learning applications in remote sensing and geospatial AI development.

10. Digital Earth Africa

Website: https://www.digitalearthafrica.org/

Features:

- Open-access satellite data platform tailored for Africa.
- Provides Sentinel-2, Landsat, and MODIS imagery.
- Supports analysis of water bodies, agriculture, and urban expansion.

Best For:

- Climate resilience, agricultural monitoring, and sustainable development in Africa.

Commercial Satellite Data Providers

While free sources provide high-quality imagery, commercial providers offer higher resolution (sub-meter) and on-demand data acquisition.

1. Maxar (DigitalGlobe)

Website: https://www.maxar.com/

Features:

- Very high-resolution (30 cm) imagery from WorldView, GeoEye, and QuickBird satellites.
- Tasking services allow custom satellite image acquisition.
- Used for defense, mapping, and disaster response.

2. Airbus OneAtlas

Website: https://oneatlas.airbus.com/

Features:

- Provides imagery from Pleiades, SPOT, and TerraSAR-X satellites.
- AI-powered image analysis for change detection.
- High-resolution (50 cm to 1.5 m) optical and SAR data.

3. Planet Labs

Website: https://www.planet.com/

Features:

- High-frequency imagery with daily global coverage.
- Datasets from PlanetScope, RapidEye, and SkySat satellites.
- AI-ready dataset for agriculture, forestry, and infrastructure monitoring.

Indian satellite data providers

1. National Remote Sensing Centre (NRSC) - ISRO

The NRSC, a part of ISRO, is the primary organization responsible for satellite data acquisition, processing, and distribution in India.

Key Features:

- Provides high-resolution satellite imagery
- Offers data from Indian and foreign satellites
- Free and paid data options
- Services available via the Bhuvan Geoportal

Available Data Sources:

- Cartosat Series (Cartosat-1, 2, 3) → High-resolution optical imagery (0.25m - 2.5m)
- Resourcesat Series (Resourcesat-1, 2, 2A) → Multispectral remote sensing (5.8m - 56m)
- RISAT Series (Radar Imaging Satellites) → Synthetic Aperture Radar (SAR) data for all-weather monitoring
- Oceansat Series (Oceansat-1, 2, 3) → Ocean color, chlorophyll, sea surface temperature
- INSAT/IMAGER (Geostationary satellites) → Meteorological and atmospheric monitoring
- HySIS (Hyperspectral Imaging Satellite) → Detailed land use and vegetation analysis

Website: Bhuvan Geoportal (bhuvan.nrsc.gov.in)

2. Bhuvan - Indian Geoportal

Bhuvan is India’s equivalent to Google Earth and offers various satellite datasets, geospatial services, and analytical tools.

Key Features:

- Free access to low and medium-resolution satellite imagery
- Thematic datasets (land use, forest cover, water bodies, etc.)
- Download Cartosat and Resourcesat imagery
- 3D terrain visualization and GIS analysis

Types of Data Available:

- Topographic data
- Thematic maps (LULC, agriculture, disaster maps, etc.)
- Disaster monitoring (cyclones, floods, landslides)
- Climate and meteorology data

Website: Bhuvan Geoportal (bhuvan.nrsc.gov.in)

3. MOSDAC - Meteorological and Oceanographic Data Archive

MOSDAC (Meteorological and Oceanographic Satellite Data Archive Centre) is an ISRO initiative that provides real-time meteorological and ocean data.

Key Features:

- Free access to INSAT and Oceansat data
- Real-time weather forecasts
- Data on rainfall, humidity, sea surface temperature, ocean color
- Used for climate monitoring, cyclone tracking, and disaster response

Available Data Sources:

- INSAT-3D & INSAT-3DR → Meteorological and cloud cover data
- SCATSAT-1 → Ocean wind speed and direction
- Oceansat-2 & Oceansat-3 → Chlorophyll concentration and sea surface temperature
- SARAL-Altika → Ocean altimetry data

Website: **MOSDAC (mosdac.gov.in)**

4. VEDAS - Visualization of Earth Observation Data and Archival System

VEDAS is a cloud-based geospatial data analysis platform developed by ISRO.

Key Features:

- Provides GIS and remote sensing analysis tools
- Used for agriculture, forestry, water resources, disaster monitoring
- Supports multi-temporal data visualization
- Access to ISRO's satellite datasets

Available Data Sources:

- Cartosat, Resourcesat, RISAT, Oceansat datasets
- Climate change and vegetation monitoring tools
- AI-based crop classification and water body mapping

Website: VEDAS (vedas.sac.gov.in)

5. IMGEOS - Indian Multi-Mission Ground Segment for Earth Observation Satellites

IMGEOS is an NRSC-operated system that provides near real-time satellite data for applications like disaster management, urban planning, and environment monitoring.

Key Features:

- Provides high-resolution data from multiple ISRO satellites
- Supports real-time disaster monitoring
- Focuses on environment, agriculture, water resources

Available Data Sources:

- Cartosat-3 (0.25m resolution optical imagery)
- Resourcesat-2 & 2A (Multispectral data for vegetation & water mapping)
- RISAT-1 & 2 (Radar data for all-weather applications)

Website: IMGEOS (nrsc.gov.in)

Indian commercial satellite data providers

1. **Pixxel (Hyperspectral Imaging)**

- Specializes in hyperspectral satellite imagery for agriculture, environment, and climate monitoring.
- Launching high-resolution hyperspectral satellites in 2025.
- Website: Pixxel (pixxel.space)

2. **SkyMap Global**

- Provides high-resolution satellite imagery from international sources.
- Specializes in infrastructure, real estate, and urban mapping.
- Website: SkyMap Global

3. **GalaxEye (Multi-Sensor Imaging)**

- Developing fusion of optical and radar imagery for cloud-penetrating Earth observation.
- Ideal for defense, disaster management, and agriculture.
- Website: **GalaxEye (galaxeye.space)**

Comparison of Indian Satellite Data Providers

Provider	Data Type	Best for	Access
NRSC - ISRO	Optical, SAR, Elevation	Land use, Urban Planning, Disaster	Free & paid
Bhuvan	Optical, DEM, Thematic	GIS Analysis, LULC, 3D Visualization	Free
MOSDAC	Meteorological, Ocean	Weather, Cyclones, Oceanography	Free
VEDAS	GIS & EO Data	Agriculture, Forestry, Hydrology	Free
IMGEOS	Near-Real-Time EO	Disaster, Infrastructure Monitoring	Paid
Pixxel	Hyperspectral	Precision Agriculture, Climate	Commercial
SkyMap Global	Optical, DEM	Commercial Applications	Paid
GalaxEye	Optical + SAR Fusion	Defense, Cloud-Penetrating Imaging	Upcoming

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Creation of shapefile in GIS software (ArcPro)

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Introduction

A Shapefile (.shp) is a widely used geospatial vector format in GIS. It consists of multiple files (.shp, .shx, .dbf) and stores points, lines, or polygons.

Steps to Create a Shapefile in ArcGIS Pro

1. Open ArcGIS Pro and Create a New Project

1. Launch ArcGIS Pro
2. Click New Project → Map
3. Name the project and set the save location

2. Creating a New Shapefile (Feature Class)

Shapefiles are stored in a Geodatabase (GDB) in ArcGIS Pro. To create a standalone shapefile, export the feature class to a shapefile.

Method 1: Using Catalog Pane (Recommended)

1. Open Catalog Pane (View → Catalog Pane)
2. Navigate to the folder where you want to store the shapefile
3. Right-click the folder → New → Shapefile
4. Choose the feature type:
   - Point (e.g., cities, trees)
   - Polyline (e.g., rivers, roads)
   - Polygon (e.g., land parcels, lakes)
5. Click OK

Method 2: Creating a Feature Class (Geodatabase)

1. Go to Catalog Pane
2. Expand Databases → Right-click the Default.gdb
3. Select New → Feature Class
4. Enter Feature Class Name
5. Choose Geometry Type (Point, Line, Polygon)

6. Set Spatial Reference (e.g., WGS 84)
7. Click Finish

To export this as a standalone shapefile:

1. Right-click the feature class → Export → Features
2. Set Output Format to Shapefile (.shp)

3. Editing and Adding Features to the Shapefile

Step 1: Start Editing

1. Go to Edit Tab → Create Features
2. Select the newly created shapefile
3. Click Point, Line, or Polygon Tool

Step 2: Add Features

1. Click on the map to draw points, lines, or polygons
2. Press Enter to finish drawing

Step 3: Save Edits

- Click Save Edits
- Click Stop Editing when done

4. Attribute Table Editing (Adding Data to Features)

1. Right-click the shapefile → Open Attribute Table
2. Click Add Field
3. Enter Field Name, Data Type (Text, Integer, Float)
4. Click Save

To update data:

- Click Edit → Modify Attributes
- Enter values and save

5. Exporting and Sharing Shapefiles

- Right-click the shapefile → Export Features
- Save as .shp in a folder
- Share via Email, ArcGIS Online, or Cloud Storage

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How to Create a Map in ArcGIS Pro: Step-by-Step Guide

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Introduction

Creating a map in ArcGIS Pro involves adding data, symbolizing layers, performing spatial analysis, and exporting the final layout. Follow these detailed steps to create a professional map.

1. Open ArcGIS Pro and Start a New Project

1. Launch ArcGIS Pro
2. Click New Project → Map
3. Enter a Project Name and set a save location
4. Click OK

2. Adding Data to the Map

Method 1: Adding Local Data (Shapefiles, CSV, Raster)

1. Go to Map Tab → Add Data
2. Navigate to the folder containing your data
3. Select the Shapefile (.shp), CSV, or Raster (.tif)
4. Click OK to load the data

Method 2: Adding Online Data (ArcGIS Online & Basemaps)

1. Go to Portal Pane → Search for layers
2. Select datasets from ArcGIS Online
3. Click Add to Map

3. Setting Coordinate System (Projection)

1. Go to View Tab → Contents Pane
2. Right-click Map → Properties → Coordinate System
3. Choose the appropriate projection (e.g., WGS 84, UTM)
4. Click OK

4. Symbolizing Layers (Changing Colors & Styles)

1. Right-click the Layer → Symbology

2. Choose from options:
    - Single Symbol (one color for all features)
    - Graduated Colors (color changes based on attribute values)
    - Unique Values (different colors for categories)
3. Adjust color, size, and transparency
4. Click Apply

5. Labeling Features

1. Right-click the Layer → Label Features
2. Open Labeling Tab
3. Choose Field (e.g., Name, Population)
4. Adjust Font, Size, Placement

6. Adding Essential Map Elements

Step 1: Open Layout View

1. Click Insert Tab → New Layout
2. Choose a Paper Size (A4, A3, Letter, Custom)

Step 2: Insert Map Elements

- Map Frame: Click Insert → Map Frame
- Legend: Click Insert → Legend → Place on Layout
- North Arrow: Click Insert → North Arrow
- Scale Bar: Click Insert → Scale Bar
- Title: Click Insert → Text → Enter Title

7. Exporting the Map

1. Click Share Tab → Export Layout
2. Choose File Format:
    - PDF (for printing)
    - PNG/JPEG (for images)
    - TIFF (high-resolution maps)
3. Click Export

8. Saving and Sharing the Map

- Save the ArcGIS Pro Project (.aprx)
- Share via ArcGIS Online or Email

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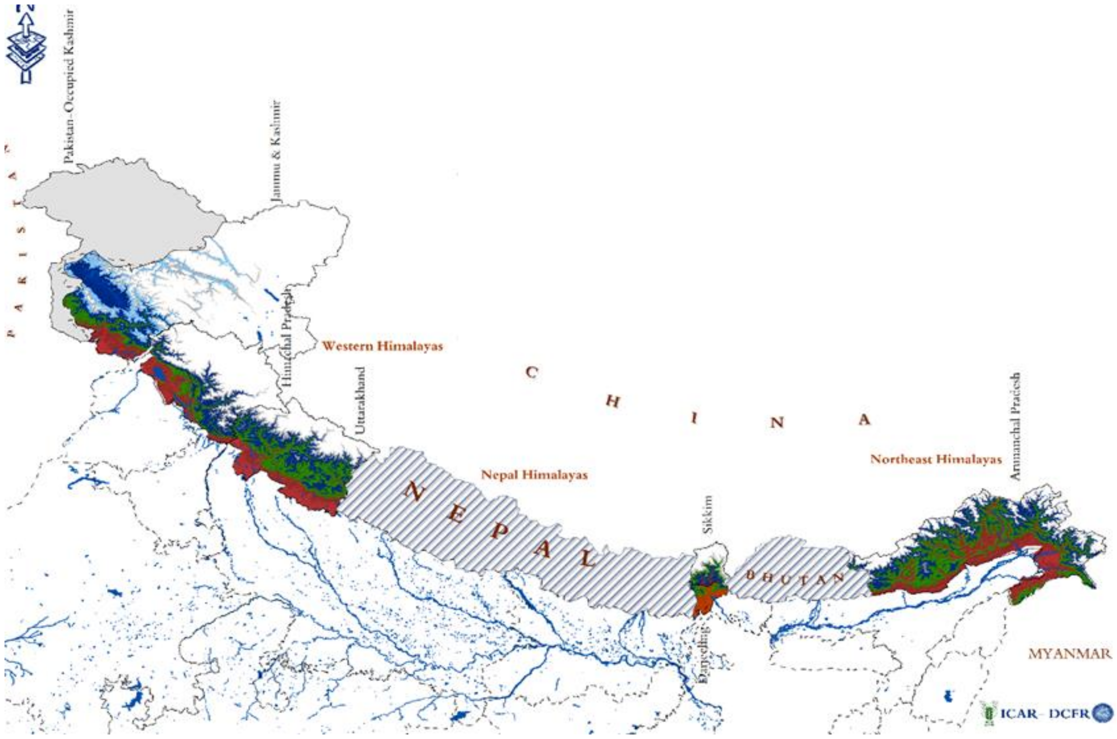

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