

Trout fisheries resources and potentialities in the Menchukha region of Arunachal Pradesh

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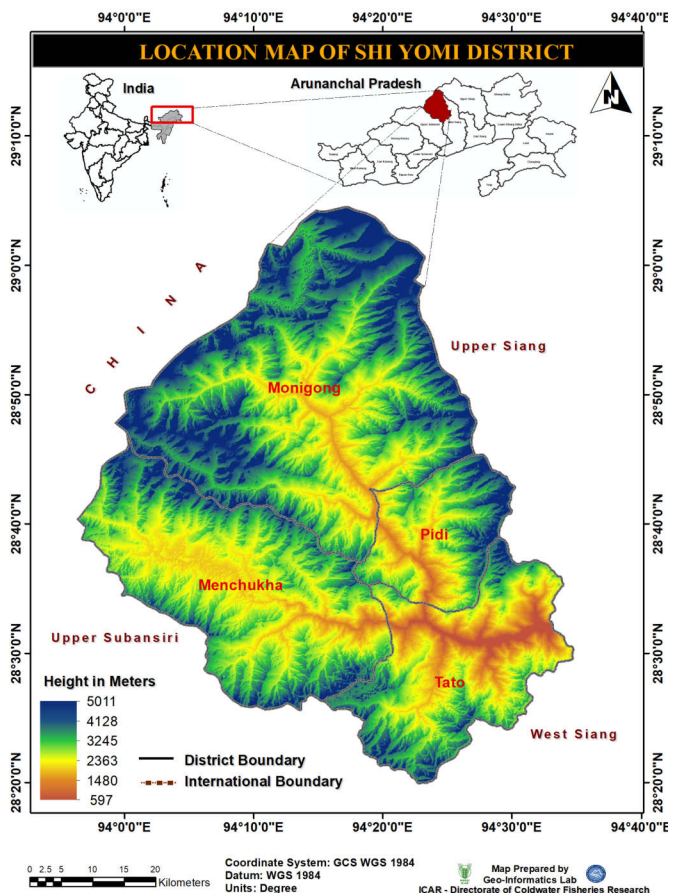
The state of Arunachal Pradesh in the eastern Himalayas is known as the land of the rising sun. This is the largest state in the north eastern region of India and home to 28 major tribes and 110 sub-tribes, with a rich heritage of arts and crafts with their own distinct and diverse culture, dialects and lifestyles.

Among the districts of Arunachal Pradesh, the district of Shi Yomi has recently been carved out of West Siang District, encompassing an area of approximately 2803 km². The major attractions of this district are its numerous perennial river drainages dissecting the mountainous terrains into deep gorges and narrow valleys. Of these, the Menchukha valley is gradually becoming a popular tourist destination on the global map due to its mesmerising beauty, gentle hills, river and snow-laden mountains. The Yargyapchu River flows through the township of Menchukha and provides a picturesque landscape to the entire valley and ample scope for recreational fisheries in the form of angling together with trekking, rafting, paragliding and camping. Together with the countryside backdrop, the Yargyapchu River has been admired as a paradise for the anglers in search of the exotic brown (*Salmo trutta fario*) and rainbow trout (*Oncorhynchus mykiss*) in this part of the eastern Himalayan belt of the country.

The fishes and aquatic resources

The climate of the district is largely influenced by the nature of the terrain, varying from sub-tropical in the south to temperate and alpine in the north, with large areas experiencing snowfalls during winter in Shi Yomi District. The surrounding snow peaks give rise to numerous rivulets, streams, lakes and tanks. The district is bestowed with two major river systems namely Siyom and Yargyapchu. A total of 44 species of fishes belonging to four orders and nine families have been identified in the Siyom. Carps are the dominant species followed by hillstream loaches of the family Balitoridae (Bagra and Das, 2010). Similarly the fish diversity of the other major drainage, namely the Yargyapchu River, is comprised of seven species belonging to four families, with carps and hillstream loaches represented by two species each (Final Report for Menchukha Hydro Power Private Limited, 2014). The low diversity of fish species in Yargyapchu may be attributed to very cold temperatures at high altitude. However, exotic rainbow trout and brown trout were introduced to the river back in the 1990s by the Department of Fisheries, Government of Arunachal Pradesh. Since then, brown trout have settled in well and at present are reported to have a good population in the Yargyapchu as hooked by the avid anglers of the region.

Location of Shi Yomi district in India.



The identification and management of habitats of these fishes has been very effective with spatial assessment of the aquatic resources and understanding the range of land use patterns affecting their distribution. Therefore, an effort has been made herewith to spatially represent aquatic resources relevant to the decision context by integrating hardware, software and data for capturing, managing, and analysing blended with non-spatial information for displaying geographically referenced information. The aquatic resources in this communication have been addressed to the major rivers, their connecting channels, streams and the wetlands in the form of upland lakes. Furthermore, the integration of GIS with site suitability criteria is expected to provide a supportive database in framing strategies and developing action plans for trout fisheries improvement in this hill locked district of Arunachal Pradesh.



Yargyapchu River giving rise to the Menchukha valley.

The drainages

The Siyom and Yargyapchu rivers flow for a distance of 59 km and 53 km respectively with very steep slopes in the upper section of the river valley. The Siyom River originates from Monigong Circle and joins the Siang River, the latter known as the mighty Brahmaputra of Arunachal Pradesh. The Yargyapchu joins the Siyom near the Tato District Headquarters. The present communication describes the characteristics of the Yargyapchu River, in particular from the perspectives of trout fisheries in the Menchukha valley.

The basic morphometry of the Yargyapchu River is of fourth order. Table 1 shows the frequency and length of different stream orders of rivers flowing through the Menchukha valley.

The first order streams are the majority followed by second and third order. The first order streams are snow-fed and form the major source of water supporting trout fishes in the Yargyapchu.

Wetlands

Wetlands form an important geographical component of eastern Himalaya as a source for the development of trout aquaculture and recreational fisheries for generating avenues for livelihood, nutrition and income. From the geo-spatial analysis it can be seen that the district of Shi Yomi is covered with 17% snow (487 ha) of the total area, mostly distributed in the regions of Monigong (360 ha) and Menchukha (75 ha). 41 wetlands are found scattered at an altitude ranging between

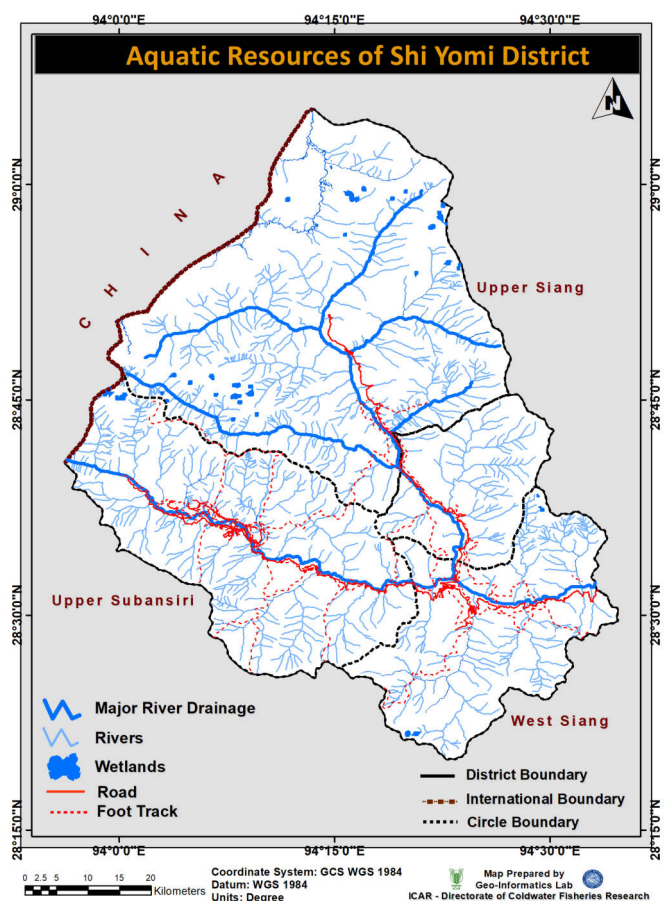
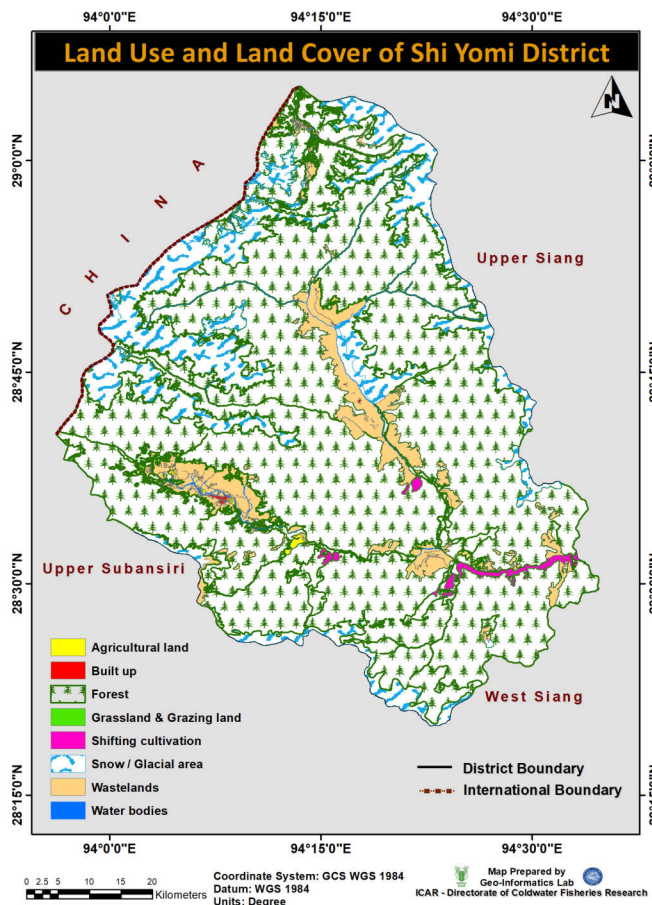
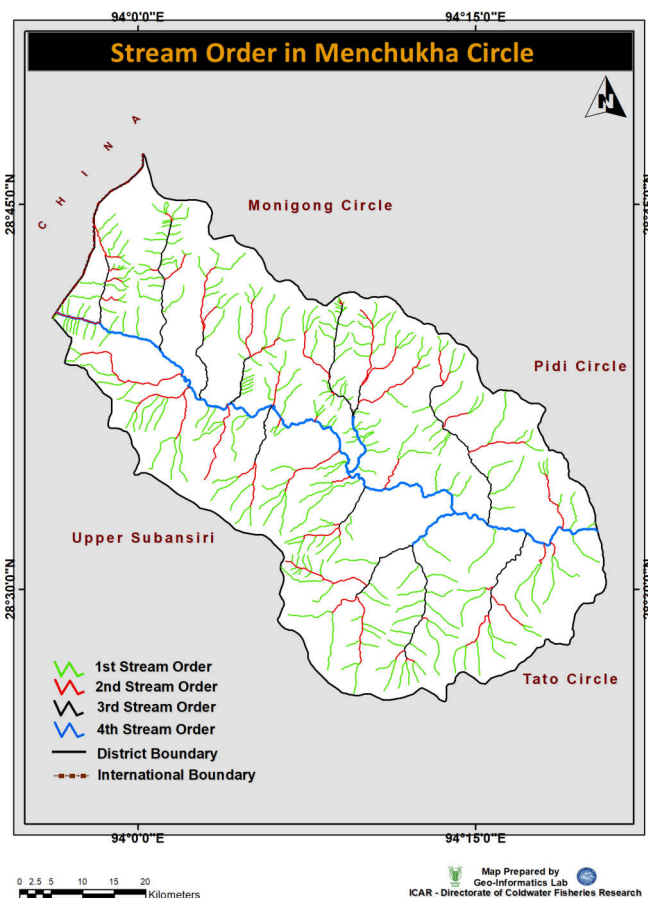
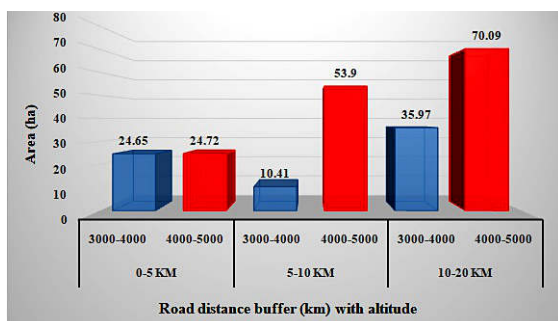


Table 1. Stream order, stream frequency and stream length of the Yargyapchu River in Shi Yomi District.

Stream order	Yargyapchu River		Shi Yomi District	
	Number	Length (km)	Number	Length (km)
1st order	296	481	975	1592
2nd order	75	139	197	419
3rd order	29	85	67	246
4th order	4	74	14	180
5th order	0	0	1	16
Total	404	779	1254	2453



Distribution of wetlands (area wise) at different altitudinal regimes and accessible distance in Shi Yomi District.



3,000-5,000 m in Shi Yomi District in the form of upland lakes covering an area of 220 hectares. The average size of the wetlands (in area) at an altitude of 4,000-5,000 m is 7.1±12.2 hectares and between 3,000-4,000 m it is 3.6±4.4 hectares. The minimum and maximum size of these wetlands between 4,000-5,000 m altitude is 0.1 and 52 hectares whereas the minimum and maximum size of wetlands between 3,000-4,000 m altitude is 0.03 and 18.7 hectares respectively. The developmental drift of these water bodies are mainly determined by their location and connectivity with the road transport lines, especially in a hill locked areas where railway and air connectivity is not prevalent. The buffer analysis showed that about 70.1% of the wetlands are scattered within the range of 10-20 km from their nearest road transport lines followed with 53.9% within 5-10 km. In both the cases the wetlands lay at an altitude regime of 4,000-5,000 m. As roads are considered the best mode of transportation for supply of critical inputs in the form of fish seed and feed in this hilly terrain, the buffer analysis provides information for designing strategic plans and programmes for development of trout fisheries in wetlands of the district.

Furthermore, the digital elevation model (DEM) examination of the district infers that the elevation class ranging from 1,000 m to 3,000 m encompassing 59% of the total geographic area can provide suitable sites for undertaking trout aquaculture activities provided the other climatic conditions are conducive. Development of a slope map generated dynamically from DEM for the district shows that the slopes in the class ranging from 0-21 degrees accounts for 28% of the total geographic area, which are more likely to include suitable sites for undertaking trout farming as compared to slopes in the class from 21-36 degrees (47% of the area) and 36-78 degrees (25% area) of the region.

Trout fisheries development in Arunachal Pradesh: Initiatives taken

The most sought after trout species for aquaculture avenues is rainbow trout whereas the brown trout is preferred for sport fishing in natural water bodies. The Yargyapchu River is a hub for angling as this drainage contains many snow-fed streams harbouring trout. However, trout aquaculture is still in its infant stage in the Menchukha valley and much more effort has to be carried forward to expand trout farming in this beautiful region. Seeing the potential of trout farming and angling, initiatives have been taken by the Department of Fisheries (DoF), Government of Arunachal Pradesh, in establishing trout hatcheries and a couple of trout farms in different districts of the state. A list of fish farms and fish hatcheries under the DoF has been depicted in Table 2. The fish farms and hatcheries established in the districts of Tawang and West Kameng only produce trout seed and fingerlings as these two districts have favourable habitat for trout. The trout hatcheries established for seed production and rearing have encouraged stakeholders to gradually commercialise their trout farms in recent times. The ICAR-Directorate of Coldwater Fisheries Research (ICAR-DCFR), Bhimtal, has been providing technical guidance in selection of suitable sites, analysing the quality and quantity of water flow and the source of inputs in establishing these hatcheries. ICAR-DCFR has provided support through trout seed consignments and assistance with hatchery facilities, together with building technical capacity of state officials and entrepreneurs through training and skill development programmes. A similar effort has been made to train and develop skills among prospective trout growers and entrepreneurs visiting ICAR-DCFR from the Menchukha region during December 2018. Visitors gained experience in trout seed production, trout rearing and subsistence utilisation of natural resources for rehabilitation of trout population for recreation and angling.

A visit to Menchukha

A February 2019 visit by a team of scientists from ICAR-DCFR and fisheries officers from the Arunachal Pradesh DoF had the objective to select suitable sites for establishing trout raceways and a trout seed production unit for development of livelihoods and nutritional support to the local communities of the valley. Effort was also made to evaluate the possibilities to establish and restore trout fisheries in the streams of the valley to create recreational fishing opportunities. During the visit, an awareness programme was initially conducted on 12th February 2019 on the topic "Coldwater fish culture in Menchukha region", which was witnessed by more than

Table 2: List of fish farms and fish hatcheries under the Department of Fisheries, Arunachal Pradesh.

District / place	Name of farm
Tawang	Chuje GG Trout Farm
	Nuranang Trout Farm
	Seru Trout Farm
West Kameng	Govt. Fish Farm, Bhalukpong
	Govt. Fish Farm, Salari
	Govt. M Trout Farm, Shergaon
East Kameng	Govt. Fish Farm, Seppa
	Govt. Fish Farm, Veo
Upper Subansiri	Govt. Fish Seed Farm, Daporijo
	Govt. Fish Seed Farm, Dumporijo
Lower Subansiri	RHA Fish Seed Farm, Tarin
	Govt. Fish Farm, Yachuli
Kurung Kumey	Govt. Fish Farm, Nyapin
Papum Pare	Govt. Fish Farm, Emchi
	Govt. Fish Farm, Gumto
West Siang	Govt. Fish Farm, Jirdin/Kambo
East Siang	Govt. Fish Seed Farm, Pasighat
	Govt. Fish Farm, Panekorong
Upper Siang	Govt. Fish Farm, Yingkiang
Lower Dibang Valley	Govt. Fish Seed Farm, Iduli
	Govt. Fish Seed Farm, Bolung
	Govt. Fish Seed Farm, Komponath
Anjaw	Govt. Fish Seed Farm, Hawaii
Lohit	Govt. MFF,TR Camp, Tezu
Namsai	Govt. Fish Seed Farm, Lathao
Changlang	Govt. Fish Farm, Diyun
	Govt. Fish Farm, Bordumsa
	RWFF, Rangkatu
Longding	Govt. TN, Miao
	Govt. TN, Changlang
	Govt. Fish Farm, Tissa
Tirap	Govt. Fish Farm, Kanubari
	Govt. Fish Farm, Deomali
Capital Complex, Itanagar	Govt. Fish Farm, Khonsa
	Experimental Fish Pond Headquarters
Dibang Valley	Nil
Siang	Nil
Kra Daadi	Nil
Pakke – Kessang	Nil
Lepa Rada	Nil
Shi Yomi	Nil
Kamle	Nil

Source: Directorate of Fisheries, Government of Arunachal Pradesh.

110 participants from different villages of Menchukha, along with officers and staff representing various associated departments. The scientists from ICAR-DCFR deliberated on the subject "Promotion of trout farming and fish based eco-tourism in upland regions of IHR". Presentations were made to the participants on:

- The fundamentals of starting of a rainbow trout farm.
- Site selection criteria for establishing concrete raceways in high altitudinal regimes.
- Undertaking trout-based eco-tourism in the Yargyapchu River and its adjoining snow-fed streams.



Trout farm at Nuranang, Tawang District under Department of Fisheries, Arunachal Pradesh.



Exposure visit of trout entrepreneurs from Menchukha at ICAR-DCFR experimental fish farm.



Skill development on trout seed production at ICAR-DCFR experimental fish farm.

- Seed production technology and hatchery management practices for raising trout in the Menchukha region.
- Determining aquaculture suitability sites through GIS mapping and ground surveys in the Shi Yomi District for promotion of trout farming.

The awareness programme was followed by an extensive field survey of the Menchukha region during 13-14 February 2019, looking for selecting suitable sites for start-up of trout farming in concrete raceways and establishing a seed production unit, both in the government and private sectors. Many potential sites were visited by the team with the help of local villagers and residents. The basic selection criteria were to have a site with a good source of quality water together with sloping terrain and road connectivity. The water quality of the Yargyapchu River along with its adjoining streams was examined by the scientists at each site and was found to be very conducive for trout farming and egg production (Table 3). The temperature, pH, dissolved oxygen, total hardness,

alkalinity and other nutrient parameters of the water were found to lie within the optimum range for trout growth and propagation. Furthermore, a certain stretch of Yargyapchu was selected by the scientists and DoF officials, in consultation with local anglers and fishers, to consider as a “protected area” with angling restricted to a few specific points. Destructive methods of fishing such as use of explosives, electricity, poisons and small meshed nets will be considered illegal in the river and streams. The entire site selected for trout aquaculture was within the slope range of 0-21 degrees, has road connectivity and was located away from agriculture and other forms of human interference. It is expected that this visit by the team of fisheries experts has benefited the entrepreneurs of Menchukha in understanding trout farming and trout based eco-tourism as a true vocation for their livelihood and income source.



Above, below: Earthen and concrete raceways at Shergaon, West Kameng District under DoF, Arunachal Pradesh.





Participants in the awareness programme, which include scientists, fisheries officers and local entrepreneurs.

Table 3: Major water quality parameters of the Yargyapchu River and its adjoining streams.

Parameters	Dorjeeling Village	Sekar Village	Lhalung Village	Nangso Village	Pemashelphu
Temperature (°C)	8.90±0.42	12.70±0.20	8.43±0.12	13.40±0.26	8.50±2.26
Air temperature (°C)	12.33±0.58	13.67±1.53	13.00±0.00	14.67±0.58	13.00±1.00
pH	8.53±0.12	8.00±0.20	7.57±0.06	7.30±0.10	8.07±0.42
DO (mg/l)	6.70±0.41	6.70±0.10	7.06±0.04	7.71±0.07	7.09±0.13
Total hardness (mg/l)	75.00	75.00	75.00	75.00	75.00
TDS (ppm)	25.33±1.15	24.67±1.15	12.00±0.00	37.33±1.15	30.00±2.00
Turbidity (NTU)	<10.00	<10.00	<10.00	<10.00	<10.00
Conductivity	010	011	00	020	001
Nitrate (mg/l)	<0.10	<0.10	<0.10	<0.10	<0.10
Iron (mg/l)	<0.20	<0.20	<0.20	<0.20	<0.20
Fluoride (mg/l)	2.50	2.50	2.50	2.50	2.50
Chloride (mg/l)	10.00	10.00	20.00	20.00	10.00
Altitude (m)	1,967	1,931	2,030	1,957	1,934

Trout angling in the Menchukha valley

The Yargyapchu River flows through the Menchukha valley at around 1,830 m altitude and for around 29 km preceding the border with the Tibet Autonomous Region (China), offering an excellent site for adventure tourism for outdoor enthusiasts with a picturesque backdrop. Government attention to the tourism and fisheries sectors in organising recreational events such as angling competitions has encouraged tourists and explorers from all over the world in recent times. Angling for brown trout in the Yargyapchu River has remained quite a fascinating adventure for anglers. A good number of sizable brown trout of 8-12 kg by weight have been hooked from

this water, which is an implausible catch elsewhere in the state. This signifies a considerable population of trout in the Menchukha area. Trout thrive in this river and provide an excellent opportunity for game fishing, generating huge income for local communities.

Introducing the concept of fee fishing in the upland lakes, ponds and tanks, together with trekking expeditions, river side camping and rafting can be an excellent way of generating income. The fish must be hooked on the basis of 'catch and release' by the anglers to preserve the existing fish stock. Furthermore, the Department of the Fisheries must be entrusted in issuing fishing licenses to anglers visiting Menchukha in order to protect the fishes from destruction. Declaration of a protected area/zone along a certain stretch

of the Yargyapchu River by the local administration will be an added advantage in allowing trout to propagate through self-recruitment. Establishment of a trout hatchery at Menchukha will help the local community and officials to ranch hatchery produced brown trout seed in the river to enhance the trout population in the valley.

GIS mapping of potential sites for trout fisheries development

The success of any aquaculture project or fish farm depends to a large extent on selection of a suitable site for establishment of a fish farm or hatchery. Site selection using the conventional method, based on very limited data, can result in inaccurate information and cause discrepancies among the implementing agencies. The utilisation of remote sensing and geographic information systems can provide a useful source of additional information. An attempt has been made herewith to identify and select potential areas where fisheries developmental activities such as culture and seed production can be carried out by employing different input feature classes.

Since the region is at over 3,000 m altitude with hilly terrain and little habitation or human population, it is presumed that the water of the region is pollution free and of the quality as desired for aquaculture operations. Thus, water quality and quantity as input criteria for site selection was considered to be optimum. Other feature classes that were taken as selection criteria were:



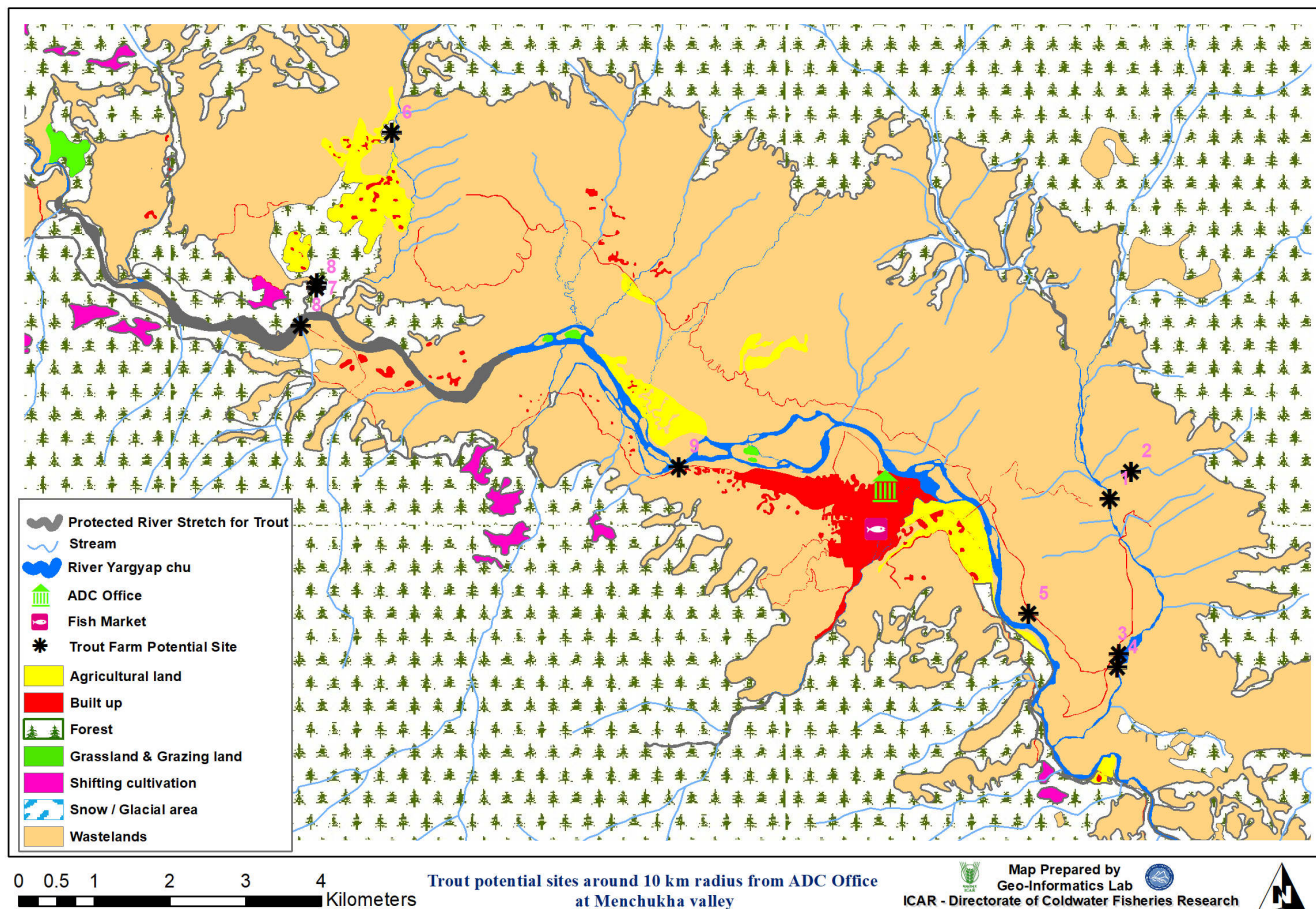
Analysing physicochemical parameters of river water to assess site suitability for trout farming.

- Drainage network, as water being the essential element for trout farming, its location and extension/spread is essential in selection process.
- Road network, due to its importance in mobilising materials from one place to another and the accessibility for supplying inputs and market the farm produce.
- Slope of the region, as it is of prime importance in hilly terrain.
- Land use land cover, to reflect the significance of land as a finite resource for human intervention for fish production coupled with economic growth.



Visit to farmers field to analyse site suitability for trout farming.

Map of the protected area on the Yargyapchu River and potential trout aquaculture sites in the Menchukha valley.



Angling of trout in the Yargyapchu River by local anglers.



Estimating the morphometric count of brown trout caught in the Yargyapchu River by local anglers.

To select a suitable area for trout farming, these input feature classes were subjected to spatial analysis using the different tools of the spatial analyst extension of the ArcGIS v 10.6.1. A buffer was drawn over the river network of the region with a spread of 100m up to the third order streams and a spread of 200m on fourth and fifth order streams with a purpose to limit the extension stretch over which trout farming operations may be initiated. In a similar way, a buffer layer of 5 km was drawn over the digitised road network input feature class of the region so as to set the distance limit under which trout farming operations are feasible and conducive. Topographic

constraints are imperative in such areas hence the limit. In case of the slope input feature class only the slope ranges of 0-10 degrees and 10-20 degrees were considered for selection, as higher slopes will be too steep for trout fish farming. Based on this, the selected input feature classes were superimposed in the GIS environment and probable trout farming areas were identified. An area of 34.77 km² in the slope range of 0-10 degrees and an area of 51.34km² in the slope range of 10-20 degrees was found suitable in the entire Shi Yomi District for undertaking trout farming provided the other requirement criteria are optimum and as per the

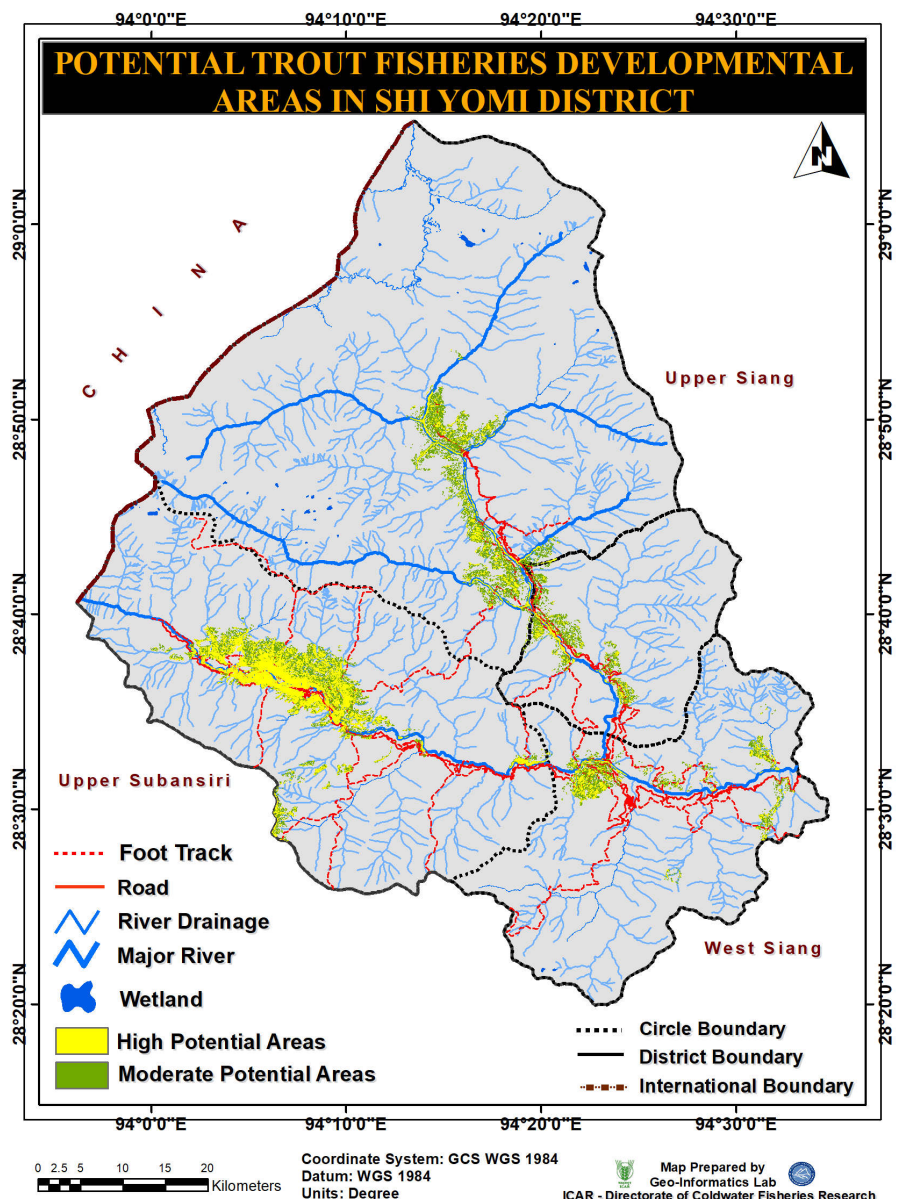
requirement for trout farming. It is noteworthy to mention here that these are only the probable areas and not the exact areas. For delineating actual suitability, a thorough and careful field examination was made during the first visit by the team to the Menchukha region.

Conclusion

Financial assistance to the trout growers by the DoF, Arunachal Pradesh, together with technical guidance by ICAR-DCFR has resulted into horizontal expansion of trout farming in the state. It is expected that this concerted effort by the department and research institutes together with participation of stakeholders will further mitigate the scarcity of trout seeds and feeds in the days to come. Establishment of concrete raceways and an ova house will further strengthen production of rainbow trout, which is the most preferred fish for culture in the region due its suitability for local habitats and substantial growth performance. On the other hand, establishment of brown trout in natural water bodies through seed ranching and preventing illegal methods of fishing, restricting anglers to follow catch and release practices and declaring a protected zone in the Yargapchu River will further enhance populations of this highly valued sport fish. Therefore Shi Yomi District has great potentiality for dissemination and uptake of trout farming and recreational fishing activities.

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