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Water quality assessment of Tehri dam reservoir in the context of its potential in aquaponics, Uttarakhand

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Abstract
The State of Uttarakhand is one of the Himalayan States having more than 3/4th of its geographical area as mountainous. Agriculture is not of commercial nature in most of its parts except in the Terai ones. The geographical constraints are hampering the traditional form of agriculture here. The reservoir of Tehri dam, having area nearly 52 Km^2, offers an opportunity to switch over to the non-traditional practices in the sector like aquaponics and that too the commercially viable ones. This soil less media can be a potential site for the new and innovative farming practices. In the study area, the water quality of the reservoir is assessed by the authors and observed that the parameters like pH, dissolved oxygen, temperature and nitrates, are quite suited to the Aquaponics with a variety of plants. Sampling has been done in Dobra Chanti, Koti, and Pipaldali all coming under lake area at various parts. The pH, DO, Temperature, Nitrate at Dobra Chanti is 9.2,8.5 ppm, 24.9 degrees, 2.3 respectively. The values for Koti are 9.23, 9.1 ppm, 22.5 degrees, 3.5 ppm respectively and for Pipaldali are 9.17, 9.3 ppm, 23.3 degrees, and 0.4 ppm respectively.
As the comparative study of the above parameters was done by [1, 2, 7] it is found that the Tehri dam reservoir has a high potential for the said bio-integrated system. Thus, the given idea facilitates that the nutrient solution may lead to an increase in commercial agriculture, agro-business which will culminate in employment opportunities and further research and development in this field. Moreover, such practices may also be carried out in the reservoir and other impounded lakes in the state.

Keywords: Water quality, reservoirs, mountains, aquaponics, sustainable agriculture, business model

1. Introduction
Aquaponics is a very innovative form of agriculture which makes a kind of ecosystem between the fish and certain plants that can grow in water. This is totally a soil less form of agriculture. Here the nutrient for the plant growth is provided by the excretory products of fish which are broken down by microorganisms so that the resultant by-product can be used [7]. This method allows a sustainable growth to the crop without using the fertilizers and chemicals as the harmless nutrients acts as a Natural fertilizers and ensure the growth of plants [1, 24]. It allows us to save maximum water that could be lost in the conventional mode of farming through percolation into the land. The Himalayan terrain is very rugged and at the same time, the water and land resources for the crop production are too limited to be viable for commercial production. At such terrains we need a very different form of agriculture that could generate more output as compared to the conventional mode. Aquaponics is one such method that is capable of producing up to three to six times the quantity of plants output of a conventional planting system [22], and utilize less amount of freshwater needed to produce fish in a conventional aquaculture system [15]. So this system is perceived to be a possible sustainable solution to the inadequacies of fish and crop production as well as unemployment and trade deficit (due to high importation of food products) in many underdeveloped and developing countries [7]. From an environmental perspective, aquaponics stands out as a resource efficient system of food production that minimizes the externalities and allows cascading of nutrients that otherwise would cause eutrophication problem in the surrounding [2, 16, 17].
We intend to develop a new model of aquaponics in mountain agriculture by utilizing the huge area of Tehri dam reservoir as an aquaponics media. Tehri dam has been a source of employment for the locals in the last couple of years. The fish production in the reservoir is at a very large scale. The idea of changing the aquaculture into aquaponics is the basic theme of the present study.

The study mainly focuses upon the utility of the water chemistry of Tehri reservoir that will provide necessary conditions for the aquaponics. A comparative analysis has been made between the water chemistry of Tehri reservoir and other aquaponics systems. The essential parameters for aquaponics like pH, DO, Temperature, Nitrate, were studied and compared.

Moreover, the Tehri reservoir is well connected to the national and the state highways and various townships with abundance of tourist inflow. This makes the idea more feasible in adopting the method for the commercial growth of aquaponics. In this way, the whole production of whole aquaponics system will be entirely organic and have a high market value.

2. Study Area

Tehri Dam is constructed near the confluence of Bhagirathi and Bhilangana rivers which is 5km downstream of submerged old Tehri town. Both the rivers are snow fed originating from the Himalayan glaciers. The rivers flow in steep banks and narrow valley. The source of Bhagirathi is Gaumukh while the Bhilangana originates from Khatling glacier. The rock formation encompassing the reservoir area belongs to phyllites of Chandpur group. The rocks are bound together with argillaceous and arenaceous materials (Ayoade *et al*., 2009).

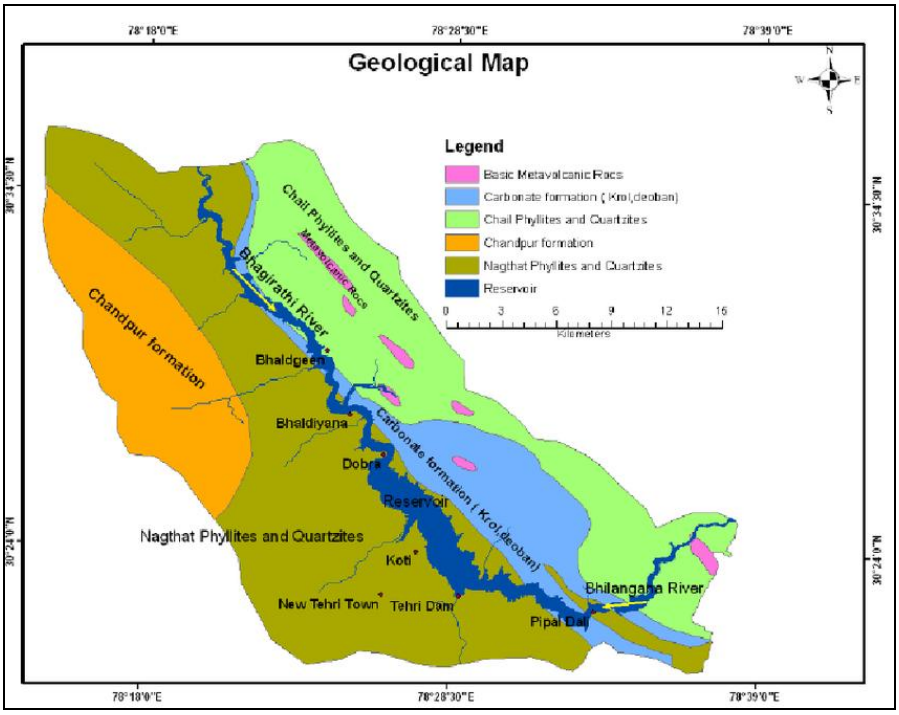

Fig 1: Geological map of Tehri reservoir area (Rupke and Sharma)

Fig 2: Satellite view of Tehri reservoir (Google Earth)

3. Material and methods

3.1. Physico-chemical parameters of water

Water samples were collected from three sites in the reservoir in the month of 26 to 27April 2019. The sampling sites were Dobra Chanti, Koti and Pipaldali. The sampling was done for pH, DO, Nitrate and Temperature. The parameters like pH, Temperature, DO were measured on field while for the Nitrate the sample was collected and taken to the laboratory for the analysis. These parameters are very important to assess the condition where the aquaponics will be carried out for the growth of fish and plants and also to ensure that the parameter values are within the optimum range

4. Results and Discussion

Table 1: Water quality parameters.

S. No.	Location	Latitude	Longitude	pH	DO	Temp.	Nitrate
1.	DobraChanti	$30^0 26' 620''$	$78^0 25' 993''$	9.2	8.5	24.9	2.3
2.	Koti	$30^0 24' 222''$	$78^0 27' 769''$	9.23	9.1	22.5	3.5
3.	Pipaldali	$30^0 22' 448''$	$78^0 32' 023''$	9.17	9.3	23.3	0.4

These values are compared with the studies done by [1, 3, 18], for the aquaponics water chemistry.
Graphical comparison of the parameters of Tehri dam with the studies done on the same parameters by in Fig. 2., Fig.3., Fig.4.,

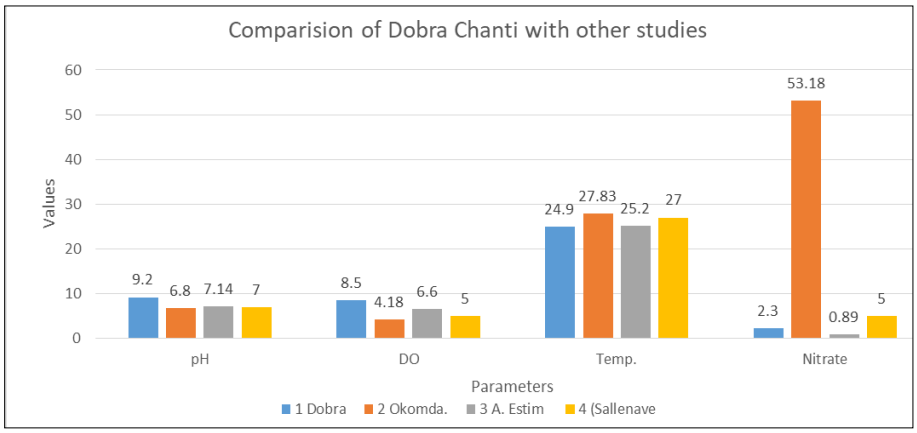

Fig 2: Showing comparison of Dobra Chanti with other studies by [1, 3, 18].

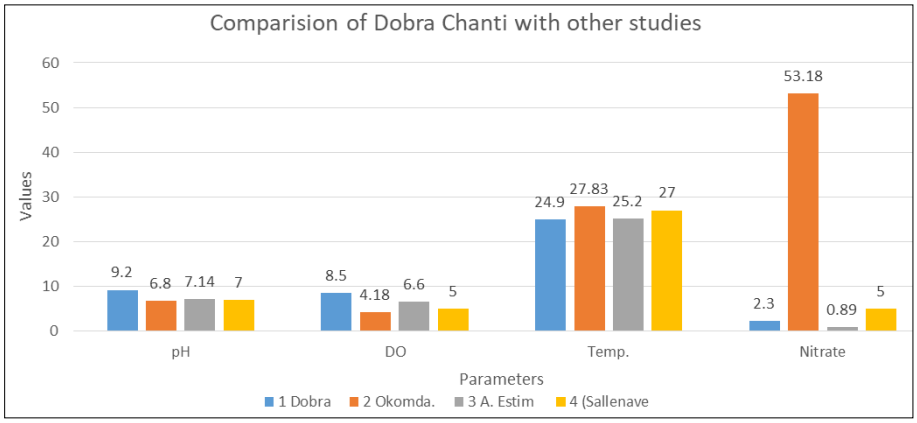

Fig 3: Showing comparison of Koti with other studies by [1, 3, 18].

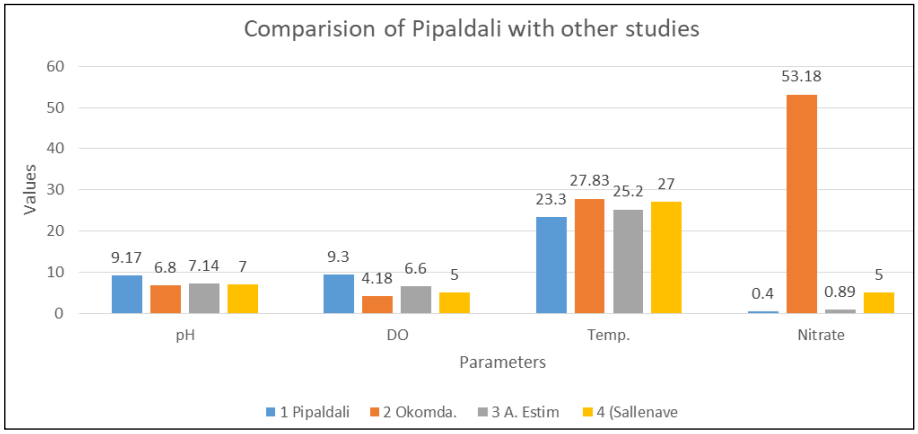

Fig 4: Showing comparison of Pipaldali with other studies by [1, 3, 18].

According to [18], DO is one of the most important parameters for fish growth and also for the beneficial nitrifying bacteria that convert the fish waste into the nutrients that plants can use. As per [18], the DO concentration levels must be greater than 5 ppm so that the various species of fishes can survive and take part as an active aquaponics member. Nitrate and pH concentrations are very much interrelated and are the key elements in aquaponics. In fact, the nitrate is a by-product of

ammonium that is initially secreted by the fishes. This ammonia is converted to nitrate by the nitrifying bacteria in two steps. According to [18], first ammonia and ammonium are converted to nitrite (NO2) by Nitrosomonas bacteria. This process requires oxygen, destroys alkalinity, produces acid (H+), and lowers pH. In the second step, nitrite (NO2), which is also highly toxic to fish, is converted to nitrate (NO3) by Nitrobacter bacteria. The second step also requires oxygen and lowers pH. The non-toxic nitrate produced in this reaction serves as plant nutrients in the hydroponic component of the aquaponics system. The nitrification process is dependent on the DO. If DO is high i.e. greater than 5ppm then the nitrification process occurs optimally else the rate becomes slow. So the pH will decrease as the nitrification goes on [18]. The recommended pH is 6 to 7 for the ideal situation.

The concentration of DO recorded in the present study was above the values reported by [18], showing that the results obtained in this study were better for tilapia growth. In addition to production from the hydroponic arrangement, the system also releases oxygen to the atmosphere through the root systems. Besides, a high concentration of dissolved oxygen in the root zone is one of the factors that could contribute to an increase in the fresh mass of plants.

The Nitrate levels must be in the range of 5-150 ppm. If the nitrate concentrations exceed the higher limits the fishes can be harvested to decrease the nitrate levels [18]. On the other hand, if the nitrate levels fall below the said range it more fishes should be put into the system to increase the nitrate levels. The same study suggests the temp. Range from 27 to 29 degrees.

In a similar study [3], concluded that the Aquaponics system did well under the various parameter range. The pH ranged from 6.80-6.92, temperature from 27.83-28.35 degrees, DO from 4.18-6.68 ppm and the nitrate from 53.18-122.3 ppm.

Furthermore, a study done by [6], shows the data of the parameters like DO, pH, NO_3 nitrogen and temperature. The temp, DO, pH, NO_3 nitrogen were 25.2 ± 0.25 °C, 6.6 ± 0.13mg/L, 7.14 ± 0.06, 0.89 ± 0.37mg/L respectively. The study says that farmers generally prefer the pH range from 6.5-9. The water quality parameters in these ranges also showed results that were satisfactory. The study also says that diseases that are caused to products in the soil were not visible in the aquaponics sustem. Hence the losses incurred by diseases are a big benefit in another way. The products obtained were green beans (*Phaseolus vulgaris*) and the Chinese cabbage (*Brassica rapa* chinensis).

Plants that have been successfully grown in aquaponics systems include lettuce, cucumbers, bell peppers, tomatoes, eggplant (with some extra care) and root crop such as carrot [12, 13, 20, 23].

5. Conclusion

Our results of the water quality parameters fall within the ranges of the studies done on aquaponics for the same parameters [1, 3, 18]. It has to be noted that the concept of aquaponics in the reservoir is new and innovative. It is very important to maintain the nutrient levels in the reservoir through massive aquaculture so that the production of the products do not show the deficiency symptoms. The pH levels are found to be high in the range of 9 and above in the reservoir but as the nitrification increases pH will go down and the production will probably increase. More the fishes more the excretion and this will lead to an increase in nutrients to the aquaponics system. In case the nutrients levels exceed the fish harvesting has to be done to reduce the excessive nutrients. The temperature is seen to be optimum for the aquaponics. DO values (greater than 5 in all sites) are best for the nitrification process and the plant growth. Although the nitrates are low in the reservoir but in the presence of mass fishing and their corresponding excretion will increase the levels of them.

A dire need is felt in mountainous parts of Uttarakhand to adopt a different mode of agriculture to gain more production and a different signature brand. Tehri reservoir provides a very good opportunity and space to adopt this form of agriculture and adding a new asset to itself apart from hydropower generation and drinking water utilities. The well connected roads around the reservoir make it economically feasible for any stake holder or entrepreneur to easily transport the products into the market with a larger margin. It is high time for the stakeholders and government to utilize this potential resource to increase the economy and employment opportunities of the people in and around Tehri. Gradually, this may check the migration from the area to a considerable extent. Further research and development in this field is an urgent need so that agro capitalism can grow in the migrating regions of Uttarakhand that may play a vital role in the economic prosperity of the state.

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