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Assessment of Groundwater Resources and Its Sustainability in the St. Martin's Island, Bangladesh

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ABSTRACT

The St. Martin's Island, the only offshore coral island in Bangladesh depends on solely groundwater for domestic uses. This study finds that groundwater occurs between 1m and 7m depths within four different aquifer lobes distributed throughout the island. These lobes are formed by deposition of beach sands within bedrock depression and are completely isolated from the influence of sea water. The model simulated groundwater budget for one of the lobes suggests that 11% of total dynamic reserve is used for water supply to local inhabitants and seasonal tourists and the rest is lost due to evapotranspiration and seepage along the boundary of the aquifer. The chemically suitable quality of potable groundwater prevails throughout the island but presence of *Escherichia coli* in the groundwater samples of the island possesses a great health threat. *E. coli* is found in 58% and 44% of the groundwater samples during dry and wet season, respectively. The unplanned construction of resorts and their septic tanks within the aquifer are responsible for the pathogenic contamination of groundwater in the St. Martin's Island. Although currently there is no threat of seawater intrusion, the rise of sea level over the bedrock barrier and storm surge inundation may destroy this resource in near future.

Introduction

The small islands of the tropical region worldwide get importance as tourist hotspots and ocean related economic activities (Gössling, 2001). In many cases, however, unsustainable tourism, agricultural and economic activities in the small islands cause the severe destruction of the island environment as well as its water resources (Ataie-Ashtiani et al., 2013; Gössling, 2001; van der Velde et al., 2007). Approximately, 50,000 small islands are located in the tropical regions of the Pacific, Indian and Atlantic Oceans and human settlements are found in 8000 islands (Robins, 2013; White et al., 2007). Small islands are usually characterized as small land area not more than 100km^2 and the terms 'small island' and 'very small islands' are often used as a broader sense to differentiate the availability of limited natural resources, especially groundwater resources (Falkland & Custodio, 1991; White & Falkland, 2010).

The tropical small islands are dependent on groundwater and rainwater which are the key freshwater resources for consumptive and other non-consumptive purposes. Floating fresh groundwater lenses over saline water in highly permeable aquifers are the typical form of groundwater in small islands (Antony et al., 2020; Ataie-Ashtiani et al., 2013; Bailey et al., 2010, 2014; Bailey & Tavakoli Kivi, 2017; Deng & Bailey, 2019; Gössling, 2001; Griggs & Peterson, 1993; Wallace & Bailey, 2017; Werner et al., 2017; White & Falkland, 2010; Colin D Woodroffe, 2008). Usually, the aquifers of small islands contain recent fluvial, glacial, marine or aeolian deposits which are permeable but thin and deposited on the impermeable platform or ancient karst limestone reefs (Falkland & Custodio, 1991; White & Falkland, 2010). The small atoll islands and reefs of the Pacific and Indian oceans are characterized by remnant volcanic structures buried under younger carbonate sediments (Murray, 1880; Vacher & Quinn, 2004; Colin D Woodroffe, 2008). Generally, dual aquifer system is possessed by these atoll islands and reefs, where an unconformity called

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'Thurber Discontinuity' or 'Holocene-Pleistocene Unconformity' separates high permeable Pleistocene limestone deposits aquifer from relatively low permeable Holocene surficial deposits aquifer (Ayers & Vacher, 1986; Bailey et al., 2010, 2014; Bailey & Tavakoli Kivi, 2017; Deng & Bailey, 2019; Vacher & Quinn, 2004; Wallace & Bailey, 2017; Werner et al., 2017; White & Falkland, 2010; C D Woodroffe, 1997; Colin D Woodroffe, 2008).

The morphology of groundwater lenses in small islands, particularly the thickness of freshwater lenses and fresh water-sea water transition zone depends on some natural and anthropogenic factors. Islands having higher groundwater recharge, wider surface area and lower hydraulic conductivity of the aquifer materials provide thicker groundwater lenses than islands having lower groundwater recharge, narrower surface area and higher hydraulic conductivity. The increased pumping of groundwater also decreases the thickness of freshwater lenses and increases the width of the fresh-saline water transition zone (Bailey et al., 2014; Volker et al., 1985; White & Falkland, 2010).

The dynamic balance between seasonal recharge from precipitation (mostly rainfall) and continuous depletion through evapotranspiration, discharge into the sea, mixing with underlying saltwater, and groundwater pumping quantify the available stored groundwater within a small island (Post et al., 2018; White et al., 2007). The quantity and quality of fresh groundwater resources in small islands are affected by their limited land areas, climatic conditions (Holding et al., 2016) and anthropogenic activities (Robins, 2013). As small islands are isolated and exposed to the open oceans, the groundwater resources are highly vulnerable to natural disasters e.g. cyclones, storm surges, droughts, saline water intrusion etc. (Bailey & Tavakoli Kivi, 2017; Dijon, 1983; Falkland & Custodio, 1991; Werner et al., 2017; White et al., 2007). The major threat to the fresh groundwater resources of oceanic islands is the contamination due to the mixing of fresh groundwater and saline water from the ocean (Robins, 2013). The intrusion of saline water to the fresh groundwater aquifer is the common phenomena for the oceanic islands which is triggered through climate change i.e. sea level rise and anthropogenic activity i.e. excessive pumping of fresh groundwater (Dijon, 1983; Griggs & Peterson, 1993; Holding & Allen, 2015). The limited freshwater resources of small islands need to be assessed both quantitatively and qualitatively to ensure their sustainability. The lack of available data, expertise and institutional framework hinders the proper resource related management options in the small islands (Holding et al., 2016).

This research paper presents the freshwater aquifer system of a small tropical island in Bangladesh, the St. Martin's Island. About seven thousands native island population (BBS, 2011) is dependent on this fresh groundwater resource for consumption. Besides, approximately hundreds of thousands of tourists annually visiting the island also utilize this groundwater for washing and bathing. Local inhabitants of the island use number 6 hand tube well for abstracting groundwater and submersible pumps are used by the resorts to meet the freshwater demand of the tourists. Despite being the only freshwater source for the island inhabitants, the availability, quality, and sustainability of this resource has never been properly assessed. Only a handful of studies are available on the island, though most are focused on the biodiversity and environmental degradation of the island (Hossain & Islam, 2006; Islam et al., 2002; Muhibbullah & Sarwar, 2017; Tomascik, 1997). Only one study (Hasan & Ahmed, 1996) assessed the groundwater chemistry of the island, which was done prior to the development of tourism in the island. Moreover, no study has characterized the aquifer system of the island and the groundwater was thought to occur as fresh water lenses overlying saline water (Hasan & Ahmed, 1996). We show that in this island, the occurrences, distribution, and the flow system of groundwater is completely different than the groundwater system usually encountered in oceanic islands.

Methods

Study Area

The St. Martin's Island is the southernmost landmass of Bangladesh and located at the northeastern part of the Bay of Bengal. This small ($8km^2$) island is completely disconnected from the mainland by a 9km wide channel (Figure 1). It is one of the most popular tourist spots for its eternal natural beauty and richest biodiversity (Muhibbullah & Sarwar, 2017). Geologically, St. Martin's Island is represented by an anticline which is a part of the Chattogram-Tripura fold belt. Unlike most of the oceanic islands the St. Martin's Island is formed due to the convergence of Indian plate and Burmese plate and the present landform of the island is created as a result of continuous geomorphic processes, sea level changes and anthropogenic activities (Hossain & Islam, 2006; Islam et al., 2002). A sequence of marine sedimentary strata is exposed on the island, ranging in age from Late Miocene to Recent. The oldest exposed rock strata is compacted grey to bluish-grey shale of the Surma Group and the youngest rock strata is fine to medium grained beach sand deposit (Islam et al., 2002). The recent beach sand deposit is the only freshwater bearing formation of this island.

Figure 1: Map of St. Martin's Island showing locations of groundwater samples in different seasons and boreholes

Field Investigations

Borehole Drilling and Installation of Monitoring Well

Thirty boreholes were drilled using auger (n=22) and hand-flapper (n=8) methods throughout the St. Martin's Island to determine the aquifer extent, depth of water table and bedrock and collect the samples of aquifer materials for laboratory analysis. A monitoring well was installed to monitor the groundwater dynamics throughout the year. Drilling depths of the boreholes and the monitoring well ranges from 0.3m to 7m. Bore logs were prepared from sediment samples collected at 6 inches intervals. Depth to water level at every borehole was determined by a digital water level meter.

Water Quality Survey and Sampling

The groundwater samples were collected from existing hand tube wells throughout the island for detailed chemical analysis in the laboratory. During pre-monsoon period (March, 2018), groundwater samples were collected from 59 locations and during monsoon period (August, 2018), groundwater samples were collected from 28 of the previously sampled locations (Figure 1) to determine the seasonal variation. A number of onsite parameters of groundwater i.e. electrical conductivity (EC), p^{H}, temperature, Eh and presence of *E. coli* were determined using field kits.

Continuous Groundwater Level Monitoring

An automatic water level logger and a barometric logger (In-Situ Rugged Troll 100) were installed inside of the monitoring well (Figure 1) to record groundwater level variations throughout the year.

Elevation Survey

An elevation survey was carried out using a total station (Sokkia CX-52) to determine the surface elevation throughout the island. XYZ coordinate of the Survey of Bangladesh Benchmark Pillar no. GPS 350A was used as the initial survey point. The land surface elevation in reference to the sea level are used to determine the topographic configuration of the island as well as to construct the cross sections throughout the island (Figure 3).

Groundwater Flow Modeling

Based on aquifer mapping and groundwater level data, a conceptual model of groundwater flow system in the island was developed. A MODFLOW model was used to verify our conceptual model of groundwater flow system. Since the aquifer become full as soon as the monsoon begins and remains full throughout the rainy season, we have only considered the dry period in the modeling exercise. The primary objective of the modeling is to reproduce the recession limb of the groundwater hydrograph using our conceptual model of groundwater flow in the island. The model consists of only one layer having 85 rows and 109 columns, with each cell being 10m in length and width, resulting in a total number of 9265 cells (Figure 2). The layer in the model represents the Uttarpara North lobe of the aquifer in the St. Martin's Island (Figure 2). The surrounding boundary of the model was assigned by drainage boundary using Drainage (DRN) package. The Drainage (DRN) package was used to facilitate seepage along the periphery of the aquifer. The aquifer was considered fully saturated as the model was simulated after end of the rainy season and no recharge was assigned at the top boundary of the model. The groundwater abstraction for domestic and tourism purposes was assigned using the Well (WEL) Package with appropriate spatial distribution. The exact value for quantifying the per capita water consumption in the study area is really a hard task. Michael and Voss (2009) considered 50 litres of water consumption per person per day in rural areas of Bangladesh (Michael & Voss, 2009); this rate was also used in this study. The model was run in a transient condition. The MODFLOW EVT package was used and evapotranspiration rate of 2 mm/day was used, this value is based on (Nachabe et al., 2005), typical for humid tropical region.

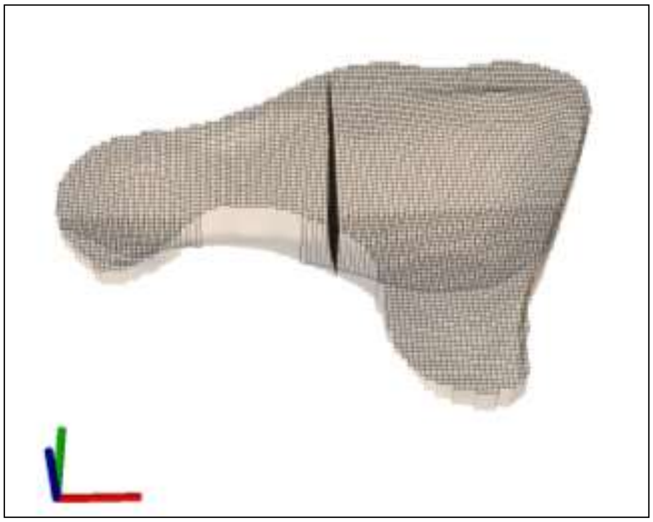

Figure 2: Groundwater model discretization

Drinking Water Quality Indexing

The water quality index (WQI) is a useful method to obtain the suitability of a water sample for drinking purpose. Considering different water quality parameters an index has been developed which indicates the overall quality of a particular water sample for drinking purpose (Antony et al., 2020; Chaurasia et al., 2018). In this study thirteen water quality parameters namely, electrical conductivity (EC), total dissolved solid (TDS), pH, sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), chloride (Cl^-), bicarbonate (HCO_3^-), sulphate (SO_4^{2-}), nitrate (NO_3^-), iron (Fe) and manganese (Mn)of the groundwater samples have been considered to determine the WQI. WQI of the groundwater samples has been calculated by using Brown's equation (Brown et al., 1972) –

$$WQI = \sum_{i=1}^{n} WiQi$$

Where, Wi is the relative weight of the ith parameter and Qi is the quality rating of the ith parameter.

Quality rating of the ith parameter (Qi) is determined by the following equation –

$$Qi = \frac{Ci}{Si} \times 100$$

Where, Ci is the concentration of the ith parameter of a groundwater sample measured in mg/l (except EC and pH) and Si is the standard value of the ith parameter according to Bangladesh.

Based on the WQI values the drinking water quality can be categorized into the following types (Sahu & Sikdar, 2008; Vasanthavigar et al., 2010) –

WQI Value Range	Water Type
<50	Excellent
50-100	Good
100-200	Poor
200-300	Very poor
>300	Unfit for drinking

Results and Discussions

Aquifers of the St. Martin's Island

Groundwater in this island occurs in recent medium to fine grained beach sand deposits ranging in thickness from 1m to 7m. Being very porous and permeable, this formation provides an excellent and very shallow unconfined aquifer of fresh water throughout the island. The shallow unconfined aquifer does not occur continuously throughout the island; rather it occurs in areas where depressions in bedrock favored the deposition of beach sediments, primarily a mixture of sand and shell fragments.

Groundwater in this island occurs in recent medium to fine grained beach sand deposits in isolated areas where there are localized basins resulting from depression in the bedrock. Based on the surface exposure of the bedrock and borehole data, four distinct lobes of the aquifer have been identified that are distributed sporadically throughout the island. These are named in this study as Uttarpara North lobe, Uttarpara South lobe, Majherpara lobe, and Dakshinpara lobe (Figure 3). Beneath the beach sand deposit, the Mio-Pliocene rock of Surma Group acts as an impermeable layer (bedrock). The thickness of these unconfined aquifer varies from 1m to 7m throughout the island (Figure 3), the maximum was found in Uttarpara North lobe (Figure 3). Although each lobes of the aquifer in the St. Martin's Island varies considerably in terms of their thickness, and volume, there are some characteristics common to each lobe. Each of the lobes is thickest at the center and thinned out to the periphery (Figure 3). Higher elevation of the bedrock along the shoreline than the center of the aquifer lobes acts as an impermeable barrier and protects the freshwater aquifer from the intrusion of the seawater. During the rainy season when the aquifer is fully saturated some of the lobes become connected to each other either via surface water channels running between them, or via the lagoons located between the lobes.

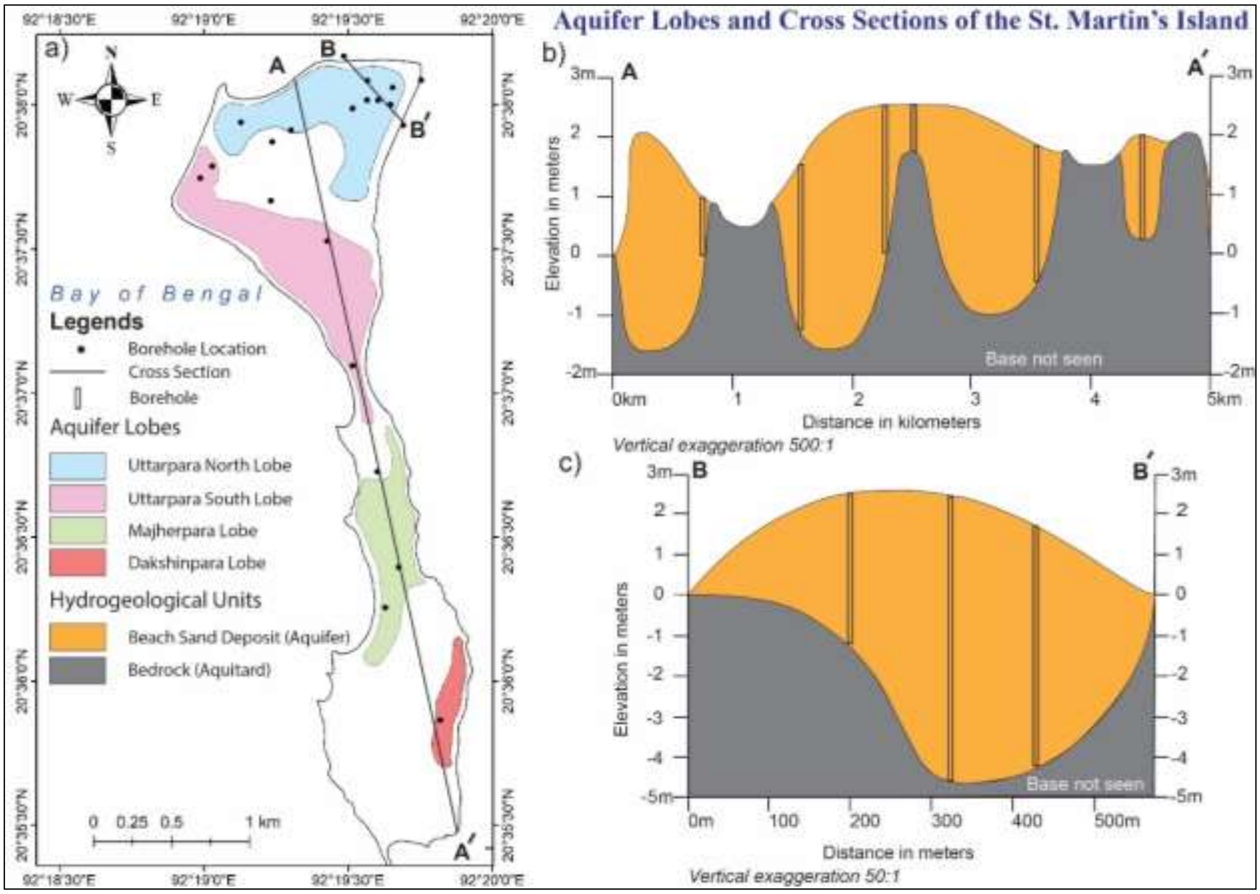

Figure 3: Schematics showing a) the distributed aquifer lobes throughout the St. Martin's Island, b) cross section along the line A-A', and c) cross section along the line B-B'

Groundwater Flow Dynamics

Groundwater level in the island is controlled by a number of factors including rapid recharge during the rainy season, natural discharge along the periphery of the aquifer lobes until the water level gets below the bedrock elevation at the periphery, evapotranspiration, and by groundwater pumping. Groundwater level data at the island reveals some interesting and unique hydrological characteristics of the aquifers. The lowest groundwater level is about 2.5m below ground level. This was observed at the end of the tourist season and before the onset of monsoon (Figure 4). Plot of rainfall data with the groundwater level expresses that as soon as the rainfall onset in this area, groundwater level rises rapidly and reaches very close to the land surface (< 0.5m) and remains there throughout the rainy season with some small fluctuations caused by gaps in rainfall events (Figure 4). After a rainfall event the aquifer gets recharged to the top and then starts discharging along the periphery and via evapotranspiration and the groundwater level declines exponentially, then another rainfall event occurs and the groundwater level rises back close to the surface rapidly, and so on (Figure 4). At the end of the rainy season and before the beginning of the tourist season, the groundwater level remains within a meter from the land surface. From that time onward tourist pumping, domestic pumping by native inhabitants, natural discharge along the periphery of the aquifer lobe and evapotranspiration result in a steady declination of the groundwater level.

The model simulated depth to water level of the aquifer in the study area shows the same trend groundwater level recession during the dry season (Figure 4) supporting our conceptual model.

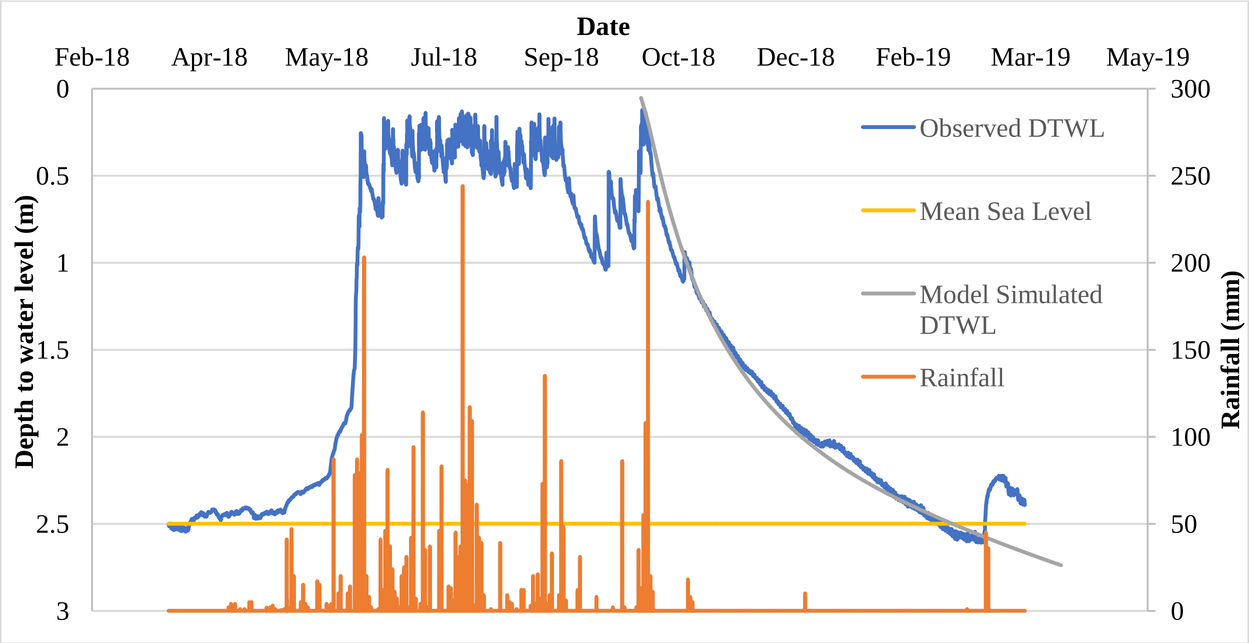

Figure 4: Hydrograph showing the hourly depth to water level i.e. DTWL (blue line) from the ground surface in the monitoring well on the St. Martin's Island for the period 23rd March 2018 to 23rd March 2019, rainfall data (bar diagram) from Teknaf station, Cox's Bazar and model simulated depth to water level (gray line)

Groundwater Availability and Demand in the Island

Both dynamic and static groundwater budget for the island has been constructed for the dry season (from November to April). The groundwater budget for the rainy season has not been considered because the aquifer lobes in the island get full within the first few days of the rainy season and remain full throughout the rainy season (Figure 4). The water demand is also less during this period because there is no tourism during rainy season. With the aid of the simulated groundwater model an extractable dynamic groundwater budget has been constructed for the Uttarpara North lobe of the aquifer. Total dynamic groundwater reserve for this lobe has been found to be 0.4 million m^3/year. Approximately 11% of the total dynamic groundwater reserve of the Uttarpara North lobe is used by the local inhabitants and seasonal tourists and 89% of the dynamic groundwater reserve is lost by the evapotranspiration and natural discharge along the boundary of the aquifer lobe.

The total static groundwater reserve at the end of the rainy season in the St. Martin's Island is 1.54 million m^3 (Table 1) considering 35% specific yield, which is typical for the beach sand deposits (Curry et al., 2004), this value is also supported by the model. Uttarpara North lobe of the aquifer shows the highest volume (0.70 million m^3) of groundwater reserve because it's relatively larger areal extent and greater thickness than other lobes (Table 1 and Figure 3). The second highest volume (0.45 million m^3) of groundwater is shown by Uttarpara South lobe. Majherpara lobe shows 0.33 million m^3 reserve of groundwater and the lowest volume (0.06 million m^3) of groundwater reserve is shown by Dakshinpara East lobe because of its smaller aerial extent and lower thickness than other lobes (Table 1 and Figure 3).

Table 1: Static groundwater balance during dry season (November to April) in the St. Martin's Island

Aquifer Lobes	Groundwater Reserve in million m^3	Island Population	Tourists per day	Demand for water supply in million m^3	ET loss in million m^3	Natural discharge in million m^3	Total loss in million m^3	Remaining reserve in million m^3
Uttarpara North Lobe	0.70	3000	2000	0.045	0.10	0.25	0.40	0.3
Uttarpara South Lobe	0.45	2000	1500	0.03	0.06	0.16	0.25	0.2
Majherpara Lobe	0.33	1500	1500	0.027	0.05	0.12	0.20	0.13
Dakshinpara East Lobe	0.06	500	NA	0.0045	0.008	0.02	0.03	0.03
Total	1.54	7000	5000	0.11	0.22	0.55	0.88	0.66

The groundwater demand in this island includes pumping for domestic use by the native inhabitants of the island, washing and cleaning water for the tourists, evapotranspiration, and natural discharge along the boundary of the aquifer lobes. The demand for groundwater supply for both the islanders and the seasonal tourists was calculated considering a daily per-capita use of 50 litres per day. The evapotranspiration rate was considered to be 2 mm/day (Nachabe et al., 2005); this is typical for dry season and very shallow aquifer, also this rate was found to be suitable to reproduce the groundwater recession curve by the flow model. Total water loss during the dry season in the entire island is estimated to be 0.88 million $m^{3.}$ Demand in Uttarpara North lobe shows the highest value (0.40 million m^3) because of its greater aerial extent leading to large evapotranspiration and greater number of local inhabitants and tourists than the other lobes (Table 1). The second highest demand (0.25 million m^3) is shown by Uttarpara South lobe (Table 1). Majherpara lobe shows 0.20 million m^3 demand of groundwater (Table 1). Dakshinpara East lobe shows the lowest demand (0.03 million m^3) of groundwater because of its lower number of inhabitants than the other lobes (Table 1).

Groundwater Quality

The overall groundwater quality of the St. Martin's Island based on the chemical constituents present in the groundwater is quite satisfactory as the good quality groundwater is prominent throughout the island for both dry and wet season (Table 2, Figure 5 and Supplementary Table 1 and 2). Unfit groundwater for potable use is traced at the south-western part of the Uttarpara South lobe during dry period but during wet period the groundwater quality of this portion became naturally remediated into poor quality water (Figure 5). In spite of being a small oceanic island the fresh groundwater of the St. Martin's Island is not contaminated by the saline water of the sea. Since each of the aquifer lobe is surrounded at their peripheries by impermeable bedrock, sea water cannot intrude into these fresh water bodies (Figure 3).

Table 2: Groundwater quality status of the St. Martin's Island for both dry and wet season based on the WQI values

WQI Value Range	Water Quality Status	Dry Season (%)	Wet Season (%)
<50	Excellent	14.55	3.70
50-100	Good	52.73	66.67
100-200	Poor	27.27	22.22
200-300	Very poor	3.64	7.41
>300	Unfit for drinking	1.82	0

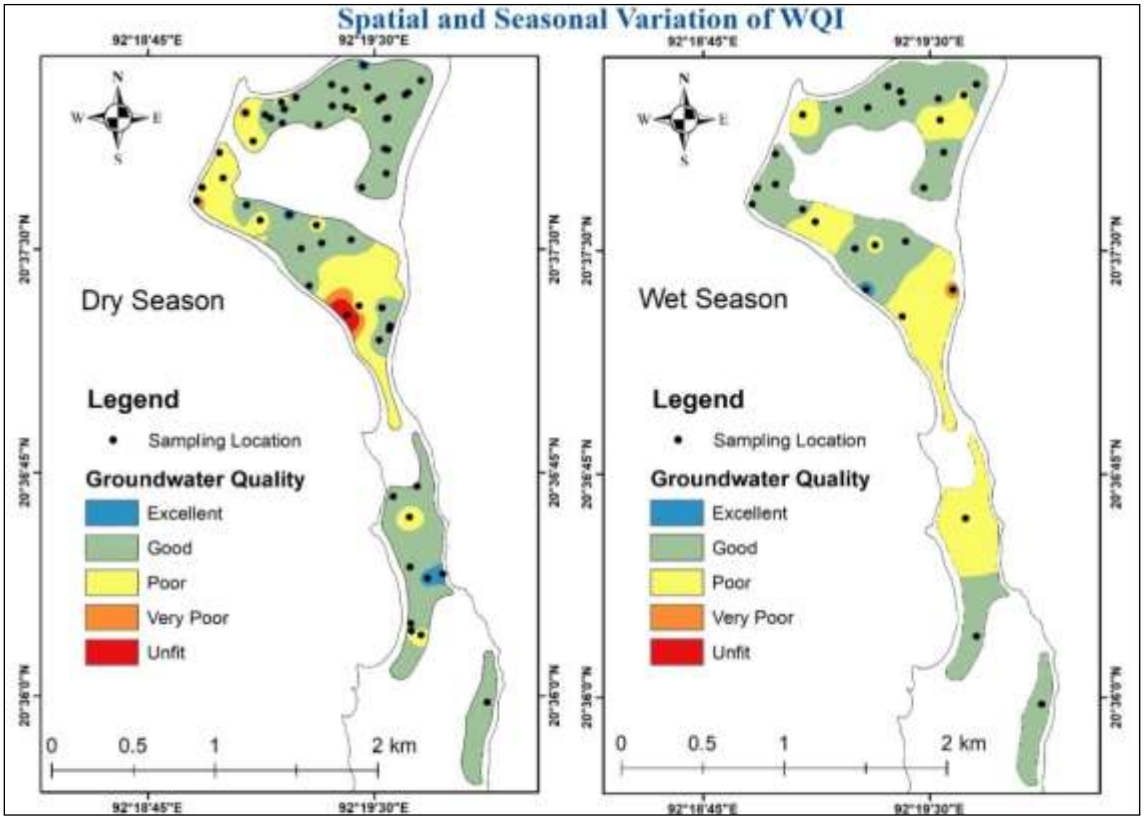

Figure 5: Maps showing the spatial and seasonal variation of WQI values of the groundwater samples in the St. Martin's Island for dry and wet season

The presence of *E. coli* in the groundwater samples of both dry and wet season of the St. Martin's Island was traced during the field investigation. During dry season 58% of the investigated groundwater samples from different aquifer lobes of the St. Martin's Island were contaminated by *E. coli* and during wet season 44% of the investigated groundwater samples were contaminated by *E. coli* (Figure 6).

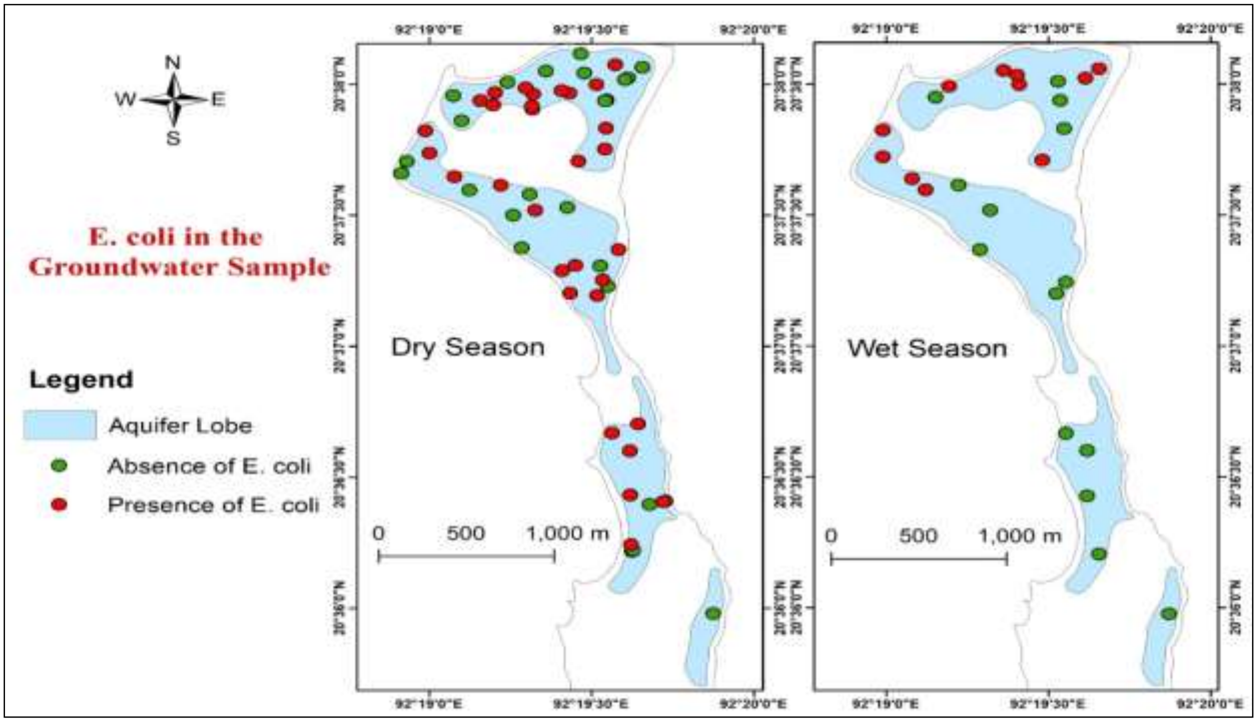

Figure 6: Maps showing the absence and presence of *E. coli* in the groundwater samples of the St. Martin's Island for both dry and wet season

Current Groundwater Vulnerability and Risks

The dynamic groundwater budget shows that the most of the dry season loss is due to evapotranspiration and natural discharge of the groundwater along the periphery of the aquifer lobes which is about 89% of the total water loss (Table 1). Groundwater abstraction for water supply constitutes only 11% of the total water loss during dry season from the aquifer (Tables 1). At the end of every dry season about 43% of the static groundwater reserve is left unused (Table 1), which is 0.66 million cubic meters. Therefore, volumetrically there is more groundwater in the island than the current demand. However, there are spatial variability in the availability and demand in groundwater, so, future tourism must be planned considering this spatial variability.

Though the groundwater quality of the St. Martin's Island based on the chemically based WQI is quite satisfactory, the presence of *E. coli* in the groundwater samples is a serious health threat for both the permanent inhabitants and the seasonal tourists of the island (Figures. 5 and 6). Contagious diseases such as diarrhea, cholera, urinary tract infection, pyogenic infection, septicemia and other water-borne diseases appear in the human body due to the ingestion of *E. coli* contaminated water (Prakash & Somashekar, 2006). The sources of pathogenic microorganisms in the groundwater are human and animal faeces and domestic wastes (Vasudevan et al., 2021). Microorganisms contaminate the groundwater due to the faulty septic and sewer systems, leaching from pit-latrines and landfills and improper management of domestic and agricultural wastes (Howard et al., 2003; Lerner & Harris, 2009; Mahmud et al., 2019; Vasudevan et al., 2021). The high permeability groundwater aquifer increases the risk of groundwater contamination through pathogenic microorganisms (Hajare et al., 2021). The septic tanks and the pit latrines of the hotels or resorts are built within the beach sand deposit which is the only freshwater bearing formation in the island. Contaminants and pathogens from the septic tanks and pit latrines would easily find its way to the aquifer as it is a sandy and high permeability formation. Moreover, unplanned construction of resorts and their septic systems due to high tourist influx in the island trigger the pathogenic contamination in the groundwater.

The absence of low permeability formation at the top of the aquifer and unplanned construction of resorts for accommodating huge tourist influx and their septic tanks within the aquifer are responsible for the pathogenic contamination of groundwater in the St. Martin's Island. The fresh groundwater of the island is exceedingly endangered due to the unplanned tourism activity and huge tourist influx during the dry season will eventually destroy the fresh groundwater resources. An immediate holistic management approach should be implemented to overcome the irreversible catastrophic consequences.

Future Risks Resulting from Climate Change and Sea Level Rise

The groundwater system is the St. Martin's Island is unique and unlike many of the small oceanic island. The isolated groundwater bodies that occurs in aquifer formed within bedrock depressions are likely to be safe from seawater intrusion as the shape of the underlying impermeable bedrock provides natural barrier. However, the rise in sea level above the top of the peripheral bedrock barrier will results in saline water intrusion in these aquifer lobes. Furthermore, the storm surges that can flood the island with saline water will cause the vertical infiltration of salt water into these aquifer lobes and ruin these resources.

Conclusion

This study aims to study the groundwater resources availability, quality, and sustainability in the St. Martin's Island, Bangladesh using a total of 30 borehole logs, one piezometer, groundwater flow modelling, and water quality analysis in 59 and 28 existing wells for both the dry and wet seasons, respectively. This study finds four isolated aquifer lobes distributed throughout the island formed by deposition of beach sands within bedrock depression and are completely isolated from the influence of sea water. Thickness of these lobes varies from 1m to 7m. This study finds that 89% of total dynamic reserve is lost due to evapotranspiration and seepage along the boundary of the aquifer and the rest is used for water supply to local inhabitants and seasonal tourists. Although the chemical quality of the water is good, presence of *E. coli* in about 50% of the groundwater samples in the island possesses a great health threat. The *E. coli* is primarily sourced from households' toilets and septic tanks of resorts located within the aquifers. Since the aquifer lobes are surrounded by impermeable bedrocks, there is no threat of seawater intrusion. However, rise of sea level over the bedrock barrier and storm surge inundation may destroy this resource in near future. The findings of this study will not only be applicable for the St. Martin's Island but also be useful for the scientific community to deal with the groundwater resources of the similar small tropical oceanic islands. The uniqueness of the occurrence, distribution and flow system of groundwater resources of the St. Martin's Island than the other small oceanic islands of the world will be able to widen the researcher's outlook on assessing the unsighted groundwater resources of the similar small oceanic islands and their vulnerability due to the both natural and anthropogenic disasters.

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