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## **Connecting Fragments and Gibbons After a Century of Separation: A Natural Canopy Bridge at the Hollongapar Gibbon Wildlife Sanctuary, Assam, India**

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**Abstract:** Habitat fragmentation resulting from linear infrastructure such as pipelines, roads or railways has emerged as one of the severest threats for wildlife globally. Among the many primate species affected by fragmented habitats, the loss of canopy connectivity in a fragmented landscape is especially detrimental to highly arboreal, canopy dwelling species, such as gibbons. The Hollongapar Gibbon Wildlife Sanctuary in Assam, India, a stronghold for the Endangered western hoolock gibbon (*Hoolock hoolock*), is bifurcated by a railway track constructed by the British in 1887. It is a barrier to the movement of wildlife in the sanctuary and the gibbons there have, since then, been isolated on either side of the track. To bridge this gap and facilitate unrestricted movement of gibbons, since 2006 we have been developing a natural canopy bridge across the railway line through coordinated tree planting, using saplings of various indigenous species on both side of the railway track along a 1-km stretch. The species selected were known to be preferred as food and sleeping trees by the gibbons. In 2019, a natural bridge was formed in one location by joining branches of the trees on either of the track. Gibbons and other arboreal species such as the capped langur, rhesus macaque and squirrels have been observed to use this canopy bridge. This natural canopy bridge has given a new lease on life to the wildlife community of the sanctuary, especially the gibbons. While the data presented here provide preliminary documentation of the natural canopy bridge and its use, further research is planned to ascertain the level of its benefit for the gibbons and other arboreal mammal species. We strongly encourage the inclusion of natural canopy bridges in the development programs involving linear infrastructure since these bridges are cost effective and extremely valuable in increasing forest connectivity.

**Key words:** Hoolock gibbon, fragmentation, isolation, mitigation, railway tracks, Assam, India

### **Introduction**

Habitat fragmentation is a severe threat to biological diversity and is considered by some to be a primary cause of the present extinction crisis (Umapathy 2020). Indeed, anthropogenic habitat fragmentation is increasing at an alarming rate throughout the world (Scto *et al.* 2012) along with a simultaneous increase in the construction of roads and other linear infrastructure elements (Reed *et al.* 1996; Santos *et al.* 2002; Oliveira *et al.* 2007; Swenson *et al.* 2011; Laurance 2018). Without increased efforts to slow the rate of fragmentation and reconnect fragments, the biodiversity crisis will continue.

Of the 20 known species of gibbons, just one—namely, the western hoolock gibbon, *Hoolock hoolock* (Harlan,

1834), occurs in India. For a time, it was thought that a second species, the eastern hoolock gibbon, *Hoolock leuconedys* (Groves, 1967), was also present in the Mishmi Hills, between the Dibang and Nao Dehing rivers in Arunachal Pradesh (Cherty *et al.* 2008, 2012). A phylogenetic analysis by Trivedi *et al.* (2021) refuted this. Although genetically similar (Trivedi *et al.* 2021), the gibbons of the Mishmi Hills are distinct in their appearance, leading Choudhury (2013, 2022) to describe them as a subspecies of the western hoolock, *Hoolock hoolock mishmiensis*. Only seven states in the northeast region of India—Assam, Arunachal Pradesh, Tripura, Manipur, Meghalaya, Nagaland and Mizoram—support the entire gibbon population in the country, limited to the southern bank of the Dibang-Brahmaputra River system.

## GIBBON CONSERVATION IN INDIA

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As a mega-biodiversity country, India supports a rich floral and faunal diversity. The order primate constitutes only a small fraction of the country's rich mammalian fauna. The total strength of the order primate in terms of number of species is only 26. These 26 species are from three different families namely Lorisidae, Cercopithecidae and Hylobatidae. The family lorisidae is represented by two species namely slow loris (*Nycticebus bengalensis*) and slender loris (*Loris lydekkerianus*). Similarly, hylobatidae family also have two representative species in India i.e. western Hoolock gibbon (*Hoolock hoolock*) and eastern Hoolock gibbon (*Hoolock leuconedys*). The cercopithecidae family has two sub-families i.e. Colobinae or leaf eating monkeys and cercopithecinae or cheek pouch monkeys. In India we have 13 colobine species viz. Golden langur (*Trachypithecus geei*), Capped langur (*Trachypithecus pileatus*), Phayre's leaf monkey (*Trachypithecus obscurus phayrei*) and Nilgiri langur (*Trachypithecus johnii*), Himalayan grey langur (*Semnopithecus ajax*), Lesser Hill langur (*Semnopithecus hector*), Central Himalayan langur (*Semnopithecus schistaceus*), Bengal Hanuman langur (*Semnopithecus entellus*), Western Hanuman langur (*Semnopithecus achates*), and Deccan Hanuman langur (*Semnopithecus anchises*). The 9 species of the subfamily cercopithecinae are Bonnet macaque (*Macaca radiata*), Long tailed macaque (*Macaca fascicularis*), Lion tailed macaque (*Macaca silenus*), Assamese macaque (*Macaca assamensis*), Pigtailed macaque (*Macaca leonina*), Rhesus macaque (*Macaca mulatta*), Stump-tailed macaque (*Macaca arctoides*), Arunachal macaque (*Macaca munzala*) and White cheeked macaque (*Macaca leucogeny*).



Adult male

Adult male female

Photo by: Udayan Borthakur

# **GOLDEN LANGUR A BEAUTIFUL SPECIES IN DANGER!!**

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## **Abstract**

Golden Langur (*Trachypithecus geei*) is one of the top most endangered primate species in the world. Zoogeographically, the species is endemic to a limited area of western Assam in India and Bhutan. Habitat loss is the severest threat to the survival of Golden Langur in the whole range of its distribution. Extirpation of the species from small fragments is an indication that habitat fragmentation is also a principal threat. Hybridization, predation by domestic dog, disease and other human-induced fatalities like vehicular accident, electrocution are other potential threats. A steep decline in the population size of the species in Bhutan is really alarming. Several laudable steps have been taken for the conservation of Golden Langur in India. Restoration of degraded habitats, rejuvenation of connectivity between fragments, management of metapopulations and an India–Bhutan joint conservation initiative are the need of the hour as far as long term conservation of Golden langur and its habitats is concerned.

**Keywords:** Golden langur, Endemic, Fragmentation, Conservation

## **1. Introduction**

The entire life forms on the earth today are facing an unprecedented crisis of sixth mass extinction. The living world had already experienced five mass extinctions over the geological time. But what makes the ongoing process of extinction a unique and more exceptional one from the previous mass extinctions is that it is more man created rather than natural phenomena. Like a giant monster the human accelerated extinction is swallowing the biological world at an alarming speed. Every day we are losing 150 species and many species are on the verge of extinction. Perhaps today every living entity is in danger and it is likely that we are going to lose many more species if proper conservation measures are not adopted at right time. Golden langur, one of the most beautiful mammalian species is also in danger today.

Every species is a fine product of organic evolution and has its own evolutionary history. The natural history of any organism could be studied in the light of its taxonomic history. Taxonomic history of an organism starts with its formal discovery by man and subsequent scientific studies elaborate and enrich this history. During the course of organic evolution, Golden langur appeared in this planet some 3.3 - 4 millions years back (Karanth, 2000). In contrast to this millions year old evolutionary history of the species, the taxonomic or documented history of golden langur is quiet short and yet to celebrate the centenary year.

The year 1953 is a very important year in the history of primatology. This was the year when naturalist E.P. Gee for the first time discovered a beautiful species which was subsequently referred as Golden langur due to its conspicuous bright orange breeding coat colour. It was a new addition to the list of primates and diversity of

# Lodging site selection by wild group of stump-tailed macaques (*Macaca arctoides*)

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## ABSTRACT

We monitored a group of 53 stump-tailed macaques from dawn to dusk, during 1998-2000 in the Hollongapar Gibbon Sanctuary, Assam, India to understand socio-ecological behaviour. We focused on identifying the lodging tree species used by stump-tailed macaques. During 1504 hours of observation, we recorded that the stump-tailed macaque group used six tree species for their lodging. *Artocarpus chama* was the most selected (preferred) species (45%) followed by *Ficus bengalensis* (35%), *Castopnopsis indica* (8%), *Ficus religiosa* (7%), *Mangifera sylvatica* (3%) and *Ficus benjamina* (2%). The average diameter at breast height of the lodging trees ranged from 0.68 to 2.4 meters and the height ranged from 20 to 35 meters. We further observed that in 85% cases stump-tailed macaques used one lodging site for one night only while 15% of their sleeping was in the same lodging tree for two consecutive nights. The study also revealed that the strong selectivity for preferred lodging sites is influenced by factors including group foraging strategies, predator avoidance and social accommodation. Above all the preference and selectivity for lodging sites is found to be critical from conservation perspective of the species.

## Conservation Status of the Golden Langur *Trachypithecus geei* in Chakrashila Wildlife Sanctuary, Assam, India

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**Abstract:** The golden langur, *Trachypithecus geei*, is among the world's 25 most endangered primates. It is endemic to India and Bhutan. Its distribution is limited to a small forest belt in western Assam in India and in Bhutan, between the River Manas in the east, River Sankosh in the west, and the Brahmaputra in the south. We carried out a survey of the golden langur in the Chakrashila Wildlife Sanctuary, the sole protected habitat for golden langurs in India, from December 2016 to March 2017. Modified line transects and total count methods were used for data collection. A total of 558 individuals in 72 groups were counted along the transects through direct sightings. Group size ranged from 2 to 18 individuals, with a mean size of 7.75. The adult male to female sex ratio was 1:2.06 and the ratio of adult females to infants was 1:0.461. The age structure of the population observed comprised 62.4% adults, 22.4% juveniles, and 15.2% infants. Encroachment, illegal tree felling, fuelwood collection and grazing by the different fringe villages are identified as major threats for golden langurs in and around the sanctuary. This information on the status and threats spectrum of the golden langur in Chakrashila Wildlife Sanctuary will help in formulating the future conservation and management guidelines.

**Key words:** Golden langur, endangered species, conservation status, Chakrashila, India

### Introduction

The golden langur (*Trachypithecus geei*) is one of the world's 25 most endangered primates (Chetry *et al.* 2017, 2019). It is found in only two countries, namely India and neighboring Bhutan. Its distribution lies north of the Brahmaputra River, bounded on the east by the Manas River, and on the west by the Sankosh River. The range in south-central Bhutan is between the Sankosh River and a high mountain ridge (running across Pele-la) in the west, and Manas River, Mangde Chu and the high mountain ridge west of Chamkhar Chu in the east (Choudhury 2008). A number of studies have been initiated to work out the exact range and total population status of the species in the two countries where it occurs (Gee 1961; Khajuria 1956, 1961; Wayre 1968; Mukherjee and Saha 1974; Mukherjee 1978, 1994, 1995; Mukherjee *et al.* 1992, 1997; Mukherjee and Southwick 1997; Subba 1989; Choudhury 1992; Wangchuk 1995; Mohnot 1995–2001,

2002). Srivastava *et al.* (2001b) estimated a population of 1,500 in India. Bhutan sustains 86% of the global population of golden langurs, the major stronghold of the species. Wangchuk (2005) estimated a population of 6,637 in Bhutan. In India, Ghosh (2009) and Biswas *et al.* (2010) sighted 5,141 individuals in 566 groups. Thus the global population of the species was estimated as >12,000 (Chetry and Chetry 2009; Horwich *et al.* 2013). Thinley *et al.* (2019), however, reported an alarming decline of the population of golden langurs in Bhutan.

The golden langur is a schedule-I species in the Bhutan Wildlife Protection Act. There it occurs in three major protected areas, namely the Jigme Singye Wangchuk (Black Mountains) National Park (173,000 ha), the Royal Manas National Park (103,300 ha) and the Phibsoo National Wildlife Sanctuary (26,600 ha). Anthropogenic pressure, changing patterns of land-tenure, developmental activities, shifting cultivation, and commercial logging are the principal threats to

## The Eastern Hoolock Gibbon *Hoolock leuconedys* Population in Assam, India, is on the Verge of Extinction

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**Abstract:** The distribution of the eastern hoolock gibbon in India is restricted to the eastern part of the state of Arunachal Pradesh and the Sadiya sub-division of Assam. The Sadiya population of the eastern hoolock gibbon is the sole population of the species in the state of Assam. A survey was conducted from January to February 2019 in three of the six reserve forests of the Sadiya sub-division to investigate the status of the eastern hoolock gibbon. Data were collected using modified line-transect surveys. We recorded seven groups in three reserve forests through direct sightings. Of the 17 individuals recorded, 14 were adults, and three were juveniles or infants. The average group size of the sighted groups was 2.42, with an adult sex ratio of 1:1. We also recorded 12 groups of rhesus macaques in the area. Rapid loss of habitat resulting from encroachment and illegal felling of trees and inadequate infrastructure are the major threats to the hoolock gibbon in Sadiya. A comparison of the present demographic data with the results of a previous study indicates that, without any immediate conservation and management intervention, this single population of eastern hoolock gibbons will be extinct in the near future. An integrated management program for the forest fragments, taking hoolock gibbon as a flagship species, could ensure the survival of the biodiversity of Sadiya, and the hoolock gibbon there.

**Keywords:** Eastern hoolock gibbon, Sadiya, habitat fragmentation, extinction

### Introduction

India has two species of gibbon: the western hoolock (*Hoolock hoolock*) and the eastern hoolock (*Hoolock leuconedys*). The seven states of Northeast India, viz. Assam, Arunachal Pradesh, Meghalaya, Manipur, Nagaland, Tripura and Mizoram support the entire gibbon population in the country. Primates are an important component of the rich biodiversity of the state of Assam. Of the 27 species of non-human primates in India, 12 species are present in Assam—Bengal slow loris *Nycticebus bengalensis*, Rhesus macaque *Macaca mulatta*, Assamese macaque *Macaca assamensis*, pig-tailed macaque *Macaca leonina*, stump-tailed macaque *Macaca arctoides*, Tibetan macaque *Macaca thibetana*, white-cheeked macaque *Macaca leucogenys*, capped langur *Trachypithecus pileatus*, golden langur *Trachypithecus geei*, Phayre's langur *Trachypithecus phayrei*, western hoolock gibbon *Hoolock hoolock*, and eastern hoolock gibbon

*Hoolock leuconedys* (Chetry *et al.* 2010; Singh *et al.* 2020). The western hoolock is found in all of the seven states of the Northeast, but the eastern hoolock gibbon is found in only two, Assam and Arunachal Pradesh (Chetry *et al.* 2007). Assam has always been considered a stronghold for the western hoolock (Chetry *et al.* 2007), and a number of studies have been carried out on its status and distribution there (Mohnot 1995–2001; Das *et al.* 2005; Chetry *et al.* 2007; Choudhury 2006, 2009; Kakati *et al.* 2009). Only in the last decade, however, was it known that the eastern hoolock gibbon occurred in the Sadiya sub-division of the Tinsukia district of Assam (Chetry *et al.* 2010), in the extreme eastern boundary of the state. Administratively, Sadiya is part of Assam, but the area has no land connection with any other part of the state, and Sadiya is continuous with the Lower Dibang valley district of neighboring Arunachal Pradesh. There are six reserve forests (RF) in the subdivision of the Sadiya range of Doomdooma Forest Division of eastern

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## Primate Diversity in the Pakke Tiger Reserve in the State of Arunachal Pradesh, India

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### ABSTRACT

The state of Arunachal Pradesh forms an integral part of Eastern Himalaya bio-diversity hotspot and by virtue of this unique bio-geography it supports rich floral and faunal diversity. Pakke Tiger Reserve in East Kameng district of Arunachal Pradesh is one of the bio-diversity rich pockets in the Northeast India. A study was conducted during 2003 to uncover the diversity and status of non-human primate in the Pakke Tiger Reserve. Data were collected by using Modified line transect method. The study confirms the presence of Assamese macaque (*Macaca assamensis*), Capped langur (*Trachypithecus pileatus*) and Slow loris (*Nycticebus bengalensis*) in the area. The study also emphasized in identifying the threats towards primates and other wildlife of the reserve. Hunting was identified to be the major threat factor to primate and other wildlife in the reserve. We feel the need for further research, awareness and community based conservation initiatives in Pakke to ensure long term conservation of the biodiversity of the region in general and primates in particular.

**Key words:** Primate, Arunachal Pradesh, Pakke Tiger Reserve, Threats and Conservation

### **Introduction**

Northeast region of India constituted by the states of Arunachal Pradesh, Assam, Meghalaya, Tripura, Nagaland, Manipur Mizoram and Sikkim is the biogeographical gateway to India's rich biodiversity. Primate is one of the important components of the magnificent bio-diversity of the region. Out of the total 26 species of primate found in India as many as 12 species inhabit the different forests of Northeast region and this is the highest diversity of primate in the country (Chetry et al., 2008, 2010; & Chetry et al., 2015). The rich tropical and subtropical forests of the state of Arunachal Pradesh are home to 10 species of primates. Borang and



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## Uphill Anion Pumping through Triangular Nanofluidic Device of Reconstructed Layered Double Hydroxide

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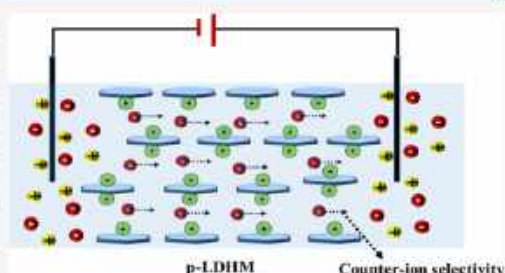
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**ABSTRACT:** Numerous research efforts have been devoted to replicate the functioning of biological ion pumps in nanofluidic devices. Unlike previous reports of cationic pumps, positively charged CoAl layered double hydroxide (CoAl LDH) is exploited here for uphill pumping of anionic species. Nanofluidic membranes prepared by self-assembling exfoliated layers of CoAl LDH exhibit excellent anionic transport characteristics. At the surface-charge-governed regime, the positively charged CoAl LDH membrane (p-LDHM) showed a remarkable  $\text{OH}^-$  ion conductivity of  $\sim 2 \text{ mS cm}^{-1}$ . The remarkable mobility of  $\text{OH}^-$  ions ( $4 \times 10^{-4} \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1}$ ) in the atomically thin channel of p-LDHM is attributed to the tiny activation energy (0.09 eV) required for Grothuss-like hopping of the ions between the positive charges of densely packed CoAl LDH layers. The lamellar p-LDHM was also found to be suitable for energy harvesting via salinity gradient, and a power density up to  $0.7 \text{ Wm}^{-2}$  was achieved under a 1000-fold concentration gradient. The triangular p-LDHM displays a diode-like nonlinear  $I$ - $V$  curve, attributed to a combination of unipolar conductivity of counterions inside the two-dimensional (2D) nanochannels and geometrical asymmetry. The triangular p-LDHM pumps anions against the concentration gradient (up to 1000-fold), under fluctuating external potentials with a mean value of zero.



### INTRODUCTION

Ion pumps with intricate transport properties play critically important roles in various physiological functions of living organisms. For example, the specific internal composition of the biological ion channels is regulated by the  $\text{Na}^+/\text{K}^+$  ion pump, which is essential for maintaining osmotic equilibrium and membrane potential of cells.<sup>1,2</sup> Similarly, plasma membrane  $\text{Ca}^{2+}$  ATPase (PMCA) is vital for regulating  $\text{Ca}^{2+}$ -ion concentration within eukaryotic cells.<sup>3,4</sup> The energy needed for the regulation of different ion pumps is supplied through sources like light, redox chemicals, and ATP.<sup>5,6</sup> Inspired by the exceptional properties of the biological ion pumps, several efforts have been devoted to fabricating their artificial counterparts.<sup>7–10</sup> Bio-inspired synthetic pumps capable of transporting ions/molecules in the uphill direction in a highly selective manner have great relevance to futuristic applications in areas like bio-sensing, environmental studies, and energy harvesting.<sup>11–13</sup> So far, most of the studies related to the biomimetic ion pumps are limited to only cation pumping. To the best of our knowledge, no progress has been made toward developing artificial ion pumps capable of transporting anions in the uphill direction. Here, we report the fabrication of an ion pump that can push anions toward a higher-concentration chamber with the help of a fluctuating electric field with a mean value of zero.

The demonstration of the feasibility of creating an unprecedentedly massive array of nanofluidic channels by restacking exfoliated sheets of layered material provided a macroscopic platform to study the nanoscale phenomena occurring at the liquid state.<sup>14</sup> By the virtue of its unique advantages such as cost-effectiveness, scalability, ease of modifications, and high-flux, reconstructed layered materials initiated a new era of nanofluidic studies. It is also creating novel avenues to exploit nanofluidic phenomena for various practical applications like harvesting of electrokinetic energy, ultrafiltration, biomedical analysis, seawater desalination, and DNA sequencing.<sup>15–20</sup> The synchronous growth in the research related to the novel two-dimensional (2D) nanomaterials further boosted the research in two-dimensional nanofluidics. After the initial demonstration with graphene oxide, numerous other layered materials such as h-BN, clay minerals, transition-metal dichalcogenide, MXenes, and carbon nitride were utilized to create nanofluidic devices with unique

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# Remarkable Rate of Water Evaporation through Naked Veins of Natural Tree Leaves

Tukhar Jyoti Konch,<sup>§</sup> Trisha Dutta,<sup>§</sup> Madhurjya Buragohain, and Kalyan Raidongia\*Cite This: *ACS Omega* 2021, 6, 20379–20387

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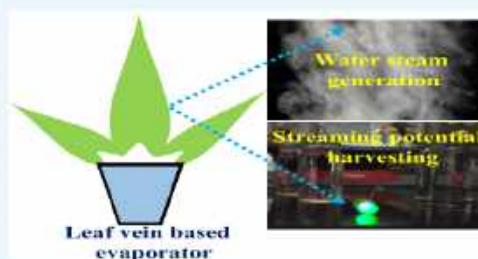
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**ABSTRACT:** In the form of leaves, nature designs the finest photo-thermal evaporators, and the tremendous evaporation efficiency of leaves is supported by a precisely designed network of veins. Here, we have demonstrated that the vein network of a natural leaf can be extracted through a simple water-assisted digestion process and exploited for low-energy steam generation. The naked leaf veins exhibit a remarkable flux (evaporation rate,  $1.5 \text{ kg}\cdot\text{m}^{-2}\cdot\text{h}^{-1}$ ) of capillary evaporation under ambient conditions ( $25^\circ\text{C}$  and 30% RH), close to the photothermal material-based evaporators reported in the recent literature. Even inside a dark box, naked veins exhibit an evaporation rate up to  $4.5 \text{ kg}\cdot\text{m}^{-2}\cdot\text{h}^{-1}$  (at 30% relative humidity (RH) and a wind speed of  $22 \text{ km}\cdot\text{h}^{-1}$ ). The mechanistic studies performed with variable atmospheric conditions (temperature, humidity, and wind speed) suggest the evaporation process through the naked veins to be a kinetic-limited process. Naked veins with remarkable evaporation efficiency are found to be suitable for applications like water desalination and streaming potential harvesting. Experiments with the naked veins also unveiled that the biofluidic channels in leaves not only exhibit the characteristics of surface charge-governed ionic transport but also support an exceptional water transport velocity of  $1444 \mu\text{m}\cdot\text{s}^{-1}$ .



## INTRODUCTION

In the past few decades, numerous unforeseen properties and phenomena specific to systems confined in a nanometer-size regime have been uncovered, and many of them have also been exploited for technological applications.<sup>1</sup> One of the recently discovered astonishing nanoscale phenomena is the enormous rate of evaporation from capillary nanochannels.<sup>2–6</sup> In spite of being an ubiquitous natural phenomenon, evaporation through nanoscale capillary channels still lacks thorough understanding and undisputed mechanism.<sup>3</sup> The remarkable evaporation efficiency demonstrated by different nanocapillary systems has been attributed to diverse mechanisms. For example, evaporation fluxes of ultrathin graphene capillaries were observed to be up to two orders of magnitude higher than the one predicted by the classical Hertz–Knudsen (H–K) equation, which was attributed to an extension of the actual evaporation areas.<sup>3</sup> Similarly, in precisely controlled experiments with hybrid two-dimensional nanochannels, Li *et al.* observed that the velocities of water vapor leaving the interface can be larger than the root mean square (RMS) velocities of vapor at the same temperature.<sup>2</sup> This extraordinary observation with individual nanochannels was credited to decreasing thermal resistance between the solid substrate and the liquid/vapor interface, along with an efficient heat and mass transfer process. Similarly, in clear contrast to the typical evaporation behavior, Gimenez *et al.* observed that sessile droplets placed on nonporous surfaces evaporate more rapidly when the salt concentration increases and the temperature decreases. This unexpected evaporation

behavior was related to the generation of a steady-state wetted annulus in the droplet periphery.<sup>4</sup>

In spite of being a poorly understood phenomenon, evaporation from nanocapillaries has an enormous impact on our ecological systems. For example, the remarkable capillary evaporation through natural tree leaves is the root of the environmental water cycle.<sup>7</sup> A natural plant leaf transpires a massive amount of water from the soil. Above 95% of the water absorbed by the roots is lost through the openings of stomata via transpiration.<sup>8,9</sup> The rapid evaporation of water through plant leaves is supported by the highly specialized network of xylem.<sup>10–12</sup> The hierarchical and porous veins provide the leaf not only with physical and chemical robustness but also with an ideal platform for the rapid evaporation of water molecules.<sup>13</sup> In this article, we have studied evaporation behavior through the hierarchical structure of the vein network extracted from the fallen leaves and exploited the same for seawater desalination. We observed that even in the absence of photoactive materials, the naked vein network exhibited an evaporation rate on a par with the man-made systems with highly efficient photothermal

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## Application of reduced graphene oxide-based actuators for real-time chemical sensing of liquid and vapour phase contaminants†

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Real-time detection of contaminants dissolved in a liquid medium is critical for various technological and industrial operations. Here, we have demonstrated the possibility of employing reconstructed layered material-based responsive membranes for the *in situ* detection of chemical contaminants in the liquid phase. A bilayer membrane prepared by sequential vacuum filtration of reduced graphene oxide (r-GO) and agar (r-GO/agar) displayed remarkable responsiveness towards the presence of solvent vapours in their surrounding atmosphere. The shape-morphing property of the r-GO/agar membrane is attributed to unequal changes in the mechanical properties of the individual components. Rectangular strips of the bilayer membrane also displayed shape-transforming properties inside the liquid medium. Depending upon the chemical nature of the molecules, inside the liquid medium, the strips of r-GO/agar membrane bend at a definite speed to adopt a coil-like shape. The original shape of the strip is easily recovered after dipping in water or drying in air. The bending angle and the response time of the r-GO/agar strips were found to be sensitive towards trace amounts of impurities present in the solvent system, which can be exploited for the detection of contaminants in the liquid phase, like trace amounts of water molecules dissolved in acetone or different alcohol molecules dissolved in toluene.

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### Introduction

The development of novel systems capable of detecting a trace amount of liquid inside another liquid medium is considered to be imperative for technological/industrial operations.<sup>1,2</sup> For example, the detection of a trace amount of an aqueous impurity in organic solvents is crucial for maintaining the safety of chemical laboratories as well as in the production of pharmaceuticals and other essential chemical compounds.<sup>3,4</sup> Similarly, the detection of organic contaminants in an aqueous medium is crucial for monitoring environmental water bodies, drinking water technologies, and food-related industries.<sup>5–8</sup> Accurate information about water content in oil also provides valuable inputs about the dynamic behaviour of different emulsion-based systems.<sup>1,9,10</sup> Likewise, aqueous contaminants critically affect the performance of lubricants, and above the accepted levels of water content, lubricants lead to abrasive wear and corrosion of machinery.<sup>2</sup>

Due to its practical importance, novel techniques have been investigated for easy, quick, and real-time detection of liquid molecules inside the matrix of another liquid. The notable examples include photoluminescence (PL)-based sensing, NMR spectroscopy-based techniques, and titration-based methods. The PL-based methods involve changes in the luminescence properties of fluorophores upon contact with water molecules, which is detected by using a fluorimeter instrument. Typical fluorophores used for this purpose are based on quantum dots, fluorescent organic molecules, metal–organic hybrid materials, metal–organic frameworks, polymers, and ceramics.<sup>9,11–16</sup> Similarly, in <sup>19</sup>F NMR spectroscopy-based sensing, anhydrous fluoride reagents are employed for the detection of a trace amount of water molecules dissolved in organic solvents.<sup>17</sup> All these processes involve highly complicated and complex synthesis procedures as well as expensive instrumentation.<sup>18</sup> Moreover, the organic water probes used in these methods are hardly recoverable and hence not suitable for long-term use.<sup>4</sup> Here, we propose an alternative method for the real-time detection of a trace amount of chemicals mixed in another liquid medium just by monitoring the shape of a smart material.

Due to their wide range of application possibilities in diverse areas such as sensing,<sup>19</sup> robotics,<sup>20</sup> drug delivery,<sup>21</sup> artificial muscles,<sup>22</sup> and space technology,<sup>23</sup> smart materials have been fabricated from a variety of materials such as polymers,<sup>24</sup>

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## The range of antiferromagnetic coupling governs the conductivity: semiconducting behavior and ammonia gas sensing property of diamagnetic hexaradical-containing tetranuclear $\text{Co}^{\text{III}}_4$ cluster and its nonradical congener†‡

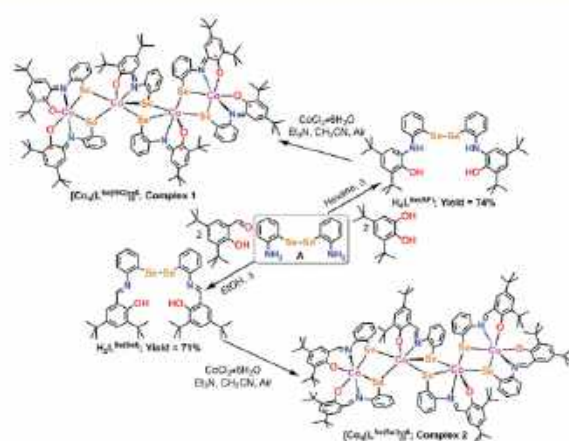
Prasenjit Sarkar,<sup>a</sup> Tukhar Jyoti Konch,<sup>a</sup> Tapas Kamilya,<sup>d</sup> Kalyan Raidongia,<sup>b</sup> Somabrata Acharya<sup>b</sup> and Chandan Mukherjee<sup>b,\*</sup>

Long-range antiferromagnetic coupling impeded electron flow through the hexaradical-containing tetranuclear  $\text{Co}^{\text{III}}_4$  complex (1), while the nonradical-containing tetranuclear  $\text{Co}^{\text{III}}_4$  complex (2), with no paramagnetic centres, was a semiconductor and sensed  $\text{NH}_3$  efficiently at room temperature (25 °C).

Ammonia gas is a harmful pollutant, which is accumulating in the environment mainly as a result of industrial and agricultural activities, decomposition of waste plants and dead animals, automotive emissions, and chemical combustion.<sup>1</sup> Exposure to ammonia gas with a concentration of more than 50 ppm causes skin and eye irritation, while exposure to higher levels, of 500 ppm, is life-threatening and causes fatal respiratory distress, including pulmonary oedema (fluid accumulation in the lungs).<sup>1c</sup> In the human body, ammonia is produced in about 0.1 ppm by natural enzymatic activities. The concentration increases to a level of about 2 ppm in cases of kidney disorder and stomach ulcers, through bacterial activity.<sup>1c</sup> Therefore, development of an ammonia gas sensor for quantification and monitoring of ammonia gas is imperative for the safety of human health and clinical diagnosis.

Over the past few decades, a lot of research on the development of ammonia gas sensors has been pursued using optical-, electrochemical-, and semiconductor-based materials.<sup>2</sup> Among these, semiconductor-based sensors are preferred due to their

long lifetime, economical benignity, and operational feasibility under harsh conditions at low potentials. In this context,  $\text{SnO}_2$ ,  $\text{ZnO}$ ,  $\text{WO}_3$ , etc., metal oxide-based semiconductors, are the most common and extensively used as gas sensors.<sup>3</sup> While the sensitivity of the oxides is good, their main drawbacks are poor selectivity, long response time, and high-temperature functionality. To deal with these issues, organic semiconductors,<sup>4</sup> nanostructured graphenes,<sup>5</sup> porphyrinoids and the corresponding metal complexes,<sup>6</sup> and metal-phthalocyanine-radical complexes<sup>7</sup> have been investigated extensively. In this study, we explore hexaradical- and nonradical-containing tetranuclear  $\text{Co}^{\text{III}}_4$  complexes. The aim is twofold: (1) understanding the origin of conductivity in the materials, and (2) use of the conducting-material-based device as an  $\text{NH}_3$  sensor at room temperature. In this regard, the non-innocent (redox-active) ligand  $\text{H}_4\text{L}^{\text{Sc(AP)}}$  and innocent salen congener, ligand  $\text{H}_2\text{L}^{\text{Sc(Sal)}}$ , have been introduced (Scheme 1). Both the ligands were synthesized in good yields by condensation reactions of bis(2-aminophenyl)diselenide (A) with



Scheme 1 Schematic representation for the synthesis of ligands and the corresponding  $\text{Co}^{\text{III}}$  complexes.

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† C. M. formulated the project and wrote the manuscript. P. S. synthesized and characterized the complexes. T. J. K. and K. R. pursued gas-sensing studies. P. S., T. K. and S. A. performed conductivity studies.

‡ Electronic supplementary information (ESI) available: Spectroscopic characterization spectra of the ligands and the complexes. Crystallographic, bond distances and bond angles tables for complex 1 and complex 2. CCDC 2067091 and 2067097. For ESI and crystallographic data in CIF or other electronic format see DOI: 10.1039/d0cc04061d

# Disposable Fluidic Devices of Bionanochannels for Enzymatic Monitoring and Energy Harvesting

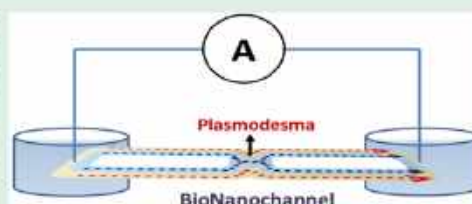
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## Supporting Information

**ABSTRACT:** Nature produces a plethora of nanochannels to carry out highly complex biological tasks in a sophisticated manner. There have been several studies to understand the characteristics of these channels; however, efforts to apply them for technological advancements are still scarce. Here, we have demonstrated that the fluidic channels of biomaterials can be harvested as nanofluidic devices to produce energy from enzymatic chemical reactions. The bionanochannel-based nanofluidic devices exhibit various nanofluidic phenomena like surface-charged-governed ionic conductivity and development of the transmembrane potential. The mobility of ions in the hydrated bionanochannels are found to be higher than that of bulk water. The cation-selective nature of the biochannels was also exploited to harvest a continuous supply of power up to 74 mW m<sup>-2</sup> for 3 h from the enzymatic decomposition of urea. The transmembrane potential across the biochannels was also explored for label-free electrical monitoring of the enzymatic reaction inside the biological medium. Electrical monitoring on the kinetics of urease at different reaction temperatures suggested that inside biological medium the reaction goes through a pathway of lower activation energy (31.1 kJ) than that in the bulk environment (34.1 kJ). Enzyme urease was found to be more sustainable in bionanochannels than in glass vials.

**KEYWORDS:** bionanochannels, nanofluidic ion-transport, ionic mobility, energy harvesting, enzyme kinetics



## INTRODUCTION

While artificial devices and machineries are providing countless conveniences to modern life, their disposals are creating major havoc in the environment.<sup>1</sup> Therefore, in recent years, numerous research efforts are being dedicated to replace unsustainable materials and devices with environmentally benign alternatives of similar functionalities. For example, different kind of electronic devices such as solar cells, diagnostic tools, sensors, electrochromic displays, and artificial tissues, etc.<sup>2–6</sup> have been developed based on sustainable materials obtained from the environment. Similarly, the outstanding new properties of liquids confined inside nanometer sized containers promise numerous technological breakthroughs in the areas of water treatment, energy harvesting, and molecular sieving.<sup>7–10</sup> Studies on confined liquid also open up an avenue to understand the activity of biological nanochannels creating a platform to exploit them for various biomedical and chemical applications.<sup>11,12</sup> However, in practice, the excellent properties of numerous biological channels readily available to us have not been explored yet for the technological applications.

*Solanum tuberosum* or potato, taken here as a model system, is one of the most widely used staple foods across the globe. It exhibits very interesting internal features in the micro and nanometer regime just like any other biological system.<sup>13,14</sup> It also possesses a highly active fluidic network across the cell walls to facilitate communications and transport of materials between the plant cells.<sup>15</sup> The transport pathways of plants are

divided into two types, the “living symplastic pathway” and the “dead apoplastic pathway”.<sup>16</sup> In the symplastic pathway, movement of masses from one cell to another cell occurs through the plasmodesmata, the narrow channels that act as an intercellular cytoplasmic gate between the cells. While in the active or regulated transport, plasmodesmata dilates to accommodate much larger macromolecules or viruses through a set of highly specific and complex molecular interactions; in the passive mode, it possesses a size exclusion limit of ~1 kDa (2–3 nm<sup>3</sup>).<sup>17</sup> In the apoplastic pathway, the mass is transported through the narrow interfibrillar and intermicellar space of the cell walls and channels formed between the adjacent cell units<sup>18–20</sup> (Figure 1a). Carpita et al. and Marchner et al. demonstrated that the nature of molecular/ionic transport through the narrow (3–5 nm) channels of the cell walls are not free or bulk-like, and it is strongly influenced by the interactions with the nondiffusible anions of the cell wall, like the carboxyl groups of the galacturonic acids of pectin.<sup>21,22</sup> Motivated by the interesting nanofluidic properties of biological nanochannels, tremendous research efforts have been devoted to prepare artificial nanochannels involving various expensive and sophisticated instrumentation. However, the abundant nanofluidic channels ubiquitous in the biological systems around us have not been considered yet for

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## Reconstruction of Soil Components into Multifunctional Freestanding Membranes

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### Supporting Information

**ABSTRACT:** Multifunctional freestanding membranes are prepared by tuning the structure of ubiquitous soil components, viz. clay and humic acids. Cross-linking of exfoliated clay layers with purified humic acids not only conferred mechanical strength but also enhanced chemical robustness of the membranes. The percolated network of molecularly sized channels of the soil membranes exhibits characteristic nanofluidic phenomena. Electrical conductivity is induced to otherwise insulating soil membranes by heating in an inert atmosphere, without affecting their nanofluidic ionic conductivity. The soil membranes also provided a new platform to prepare and study mixed conducting materials. Strips of heated membranes are shown to exhibit excellent sensitivity toward  $\text{NH}_3$  gas under atmospheric conditions.



### 1. INTRODUCTION

Soil, also known as the skin of the earth, is a highly complicated but a synergic mixture of living and nonliving objects.<sup>1,2</sup> It plays pivotal roles in the environmental chemical cycles and provides a basis for the survival of life on earth. Among various nonliving objects in soil, clays and humic acids (HAs) are the most active constituents, and in spite of their drastically different chemical and physical identities, they contribute similarly to the chemical functionalities of soil. For example, both clays and HAs actively participate in detoxification of hazardous substances, preservation of vital minerals, and maintenance of ideal pH, fertility, and air/water ratios for plant growth.<sup>1–6</sup> Studies suggested that the activities of clay and HAs complement each other and an appropriate combination of the two is essential to obtain certain crucial functionalities of soil.<sup>1–10</sup> Nonetheless, rational blends of these two naturally abandoned materials have not been optimally applied with a view to creating advanced materials for futuristic applications. Here, we attempt to utilize the ubiquitous chemistry of HAs and clays to prepare multifunctional freestanding membranes with application possibilities in the areas like nanofluidic energy harvesting, water purification, and sensing of toxic chemicals. To facilitate better interactions, layers of naturally occurring vermiculite clay were exfoliated into ultrathin 2D sheets, and HAs were purified through multiple steps of conjugative acid–base treatments.

Clays are stacking layers of hydrous aluminum phyllosilicates consisting of corner-sharing  $\text{SiO}_4$  tetrahedra and/or  $\text{AlO}_4$

octahedra intercalated by aqueous solutions of charge-balancing cations. Owing to their well-defined structures having high chemical and thermal stability, clay minerals have received lots of attention from the scientific communities across the disciplines. As a result, they are being applied in a variety of advanced technologies such as nuclear waste managements, industrial oil absorbance, pharmaceuticals, and anticaking applications.<sup>11</sup> Clays are also highly tuneable and can be easily modified to create freestanding proton-conducting membranes, ultrasensitive smart materials, and a range of polymeric nanocomposites.<sup>12–15</sup> On the other hand, HAs are mixtures of acidic organic polymers that are believed to be a product of the natural break-down process of plant- and animal-based materials.<sup>16,17</sup> There have been significant contradictions regarding the origin and structure of HAs. However, their favorable contributions toward environmental chemical cycles have been proven beyond doubt. The phenolic and carboxylic functional groups of HAs together with negative surface charges of clay layers are the major contributors of the cation exchange capacity of soil, and hence, contents of the two are a primary characterization of soil nature. Unfortunately, the application of HAs in advanced technologies is limited by its complicated and undefined structures. They are being utilized as a cheap source of carbon, either to generate heat through

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## A two-dimensional ion-pump of a vanadium pentoxide nanofluidic membrane†

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The reactive surface and layered crystal structure of vanadium pentoxide ( $V_2O_5$ ) are exploited here to prepare a two-dimensional (2D) ion pump that transports ions against their concentration gradient. The exfoliated layers of  $V_2O_5$  were assembled into membrane form to create ion-channels with excellent nanofluidic transport characteristics. At the surface-charge-governed regime, the flexible and freestanding membrane of  $V_2O_5$  showed a remarkable proton conductivity ( $\sim 0.01 \text{ S cm}^{-1}$ ). The activation energy of proton conductivity (0.066 eV) suggests that the exceptional mobility of  $H^+$  ions ( $5.2 \times 10^{-3} \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1}$ ) inside  $V_2O_5$  ion-channels originates from the coordinated hopping of charges between the two-dimensionally arranged water molecules. The transport characteristics of  $V_2O_5$  ion-channels can also be tuned just by tailor-cutting its lamellar membranes into different shapes. While rectangular devices of  $V_2O_5$  membranes exhibit linear  $I$ - $V$  curves, the triangularly cut membranes display a diode-like non-linear  $I$ - $V$  curve. The ionic current rectification in the  $V_2O_5$  triangle was found to originate from a combination of the unipolar conductivity of counter-ions inside the 2D nanochannels and geometrical asymmetry. The 2D ion rectifier of  $V_2O_5$  also pumps ions at the rate of  $3.32 \times 10^{-8} \text{ amp s}^{-1}$  against a 1000-fold concentration gradient under a fluctuating external potential with zero mean.

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## Introduction

Channels capable of pumping ions against their concentration gradient at the expense of energy derived from ATP hydrolysis are ubiquitous in biology.<sup>1</sup> They not only help cells to communicate with other cells or external environments but also essential for processes like maintaining cellular ion homeostasis and energy conversion. The outstanding transport properties of biological ion-pumps have also inspired researchers to develop artificial nanochannels capable of producing directional movement of ions because such ion-pumps would be crucial for applications like bio-sensing, bio-purification, seawater desalination, and energy harvesting. So far, most of the experimental and theoretical efforts devoted to creating artificial ion pumps are limited to three-dimensional conical nanopores or artificial protein pumps.<sup>2-7</sup> Here, we have demonstrated that atomically thin 2D channels of a triangular vanadium pentoxide membrane can also pump ions against their concentration gradient in the presence of a fluctuating external potential with zero mean. The reconstructed layered 2D ion-pump displays distinct advantages like facile fabrication and scalability. A large number of 2D materials and their

possible functionalized derivatives offer several ways to tune parameters like ionic flux and pumping efficiency. Functionalization of the building blocks could also lead to creation of new functionalities like photo-switchable<sup>8</sup> or temperature-switchable smart ion-pumps. Moreover, the macroscopic dimensions of the nanochannel assemblies overcome the requirement of expensive and sophisticated devices to fabricate devices and offer new opportunities to study the interesting ion transport properties.

Named after the Scandinavian goddess of beauty and fertility, vanadium forms an exceptionally rich variety of oxides that exhibit a range of fascinating properties like metal-insulator transitions, photochromism, thermochromism, and electrochromism.<sup>9-12</sup> These unique properties also provide a platform for the development of many futuristic applications like electrical/optical switching devices, smart windows, and variable reflectance/emittance surfaces.<sup>13-15</sup> Variable oxidation states and the exceptionally active surface of vanadium oxides are also exploited for preparing catalysts for several industrially important chemical processes like manufacturing of sulfuric acid, synthesis of phthalic anhydride, and reduction of nitrogen oxides from the flue gas of power plants.<sup>16</sup> Likewise, tremendous amounts of research efforts are being devoted to exploit the layered-crystal structure and high specific capacity of vanadium oxides to prepare electrode materials for energy storage technologies like lithium/sodium/zinc ion batteries and supercapacitors.<sup>17-20</sup> However, the active surface and

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† Electronic supplementary information (ESI) available: Materials, methods, characterization, fabrication of devices and Fig. S1-S12 and Table S1. See DOI: 10.1039/c8ta11233a



## Water and salt dynamics in multilayer graphene oxide (GO) membrane: Role of lateral sheet dimensions



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### ARTICLE INFO

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Water permeability  
Salt rejection  
Molecular dynamics simulation  
Pore offset distance

### ABSTRACT

Dependence of salt rejection efficiency and water permeability of layered graphene oxide (GO) membranes on the lateral dimension of constituting sheets are studied through equilibrium molecular dynamic (MD) simulation and experiments. This study suggests that with increasing sheets dimension permeability of the GO membranes decreases but its selectivity increases. The velocity and permeation time of the water molecules while permeating through the membrane are influenced to a greater extent by the pore offset distance ( $W$ ) of the membranes. More over the larger pore offset distance increases the path length that the water molecules and ions have to traverse for permeating through the layered GO membranes. Based on the simple technique discussed in this work, one can construct GO membranes of required water permeability and salt rejection without the application of any foreign nanomaterials with the GO membrane, which retains the inherent selectivity of the GO membranes. This work also provides the effect of internal structure of GO membrane on the atomistic level details of the solvation shell of ions while they are permeating through the membrane.

### 1. Introduction

The growing demand of fresh water with the rapid growth of human civilization urges the researchers to search for efficient and cost effective water desalination/purification techniques. On this important note, Graphene oxide (GO), a unique blend of hydrophilic and hydrophobic nano-regime confined at strictly two-dimensional sheet morphology [1] has emerged as one of the most extensively studied materials in the last decade [2–4]. Removal of solvent molecules from GO dispersions yields a layered structure and the interlayer spacing between the GO layers serves as the nano-channel for water permeation [5–11]. Due to its extremely large lateral dimensions, GO sheets readily self-assemble into freestanding lamellar membranes, where the interlayer spacing between the sheets serves as an interconnected network of ionic and/or molecular channels [12,13]. Experimentally the interlayer distance between stacked GO sheets was found to be ranged from 6 to 11 Å [14,15]. Wei et al. [4] found the interlayer separation between the GO sheets ranges from 7.5 Å to 12.4 Å in their molecular dynamics simulations. The water diffusivity increases with an increase in interlayer distance between the successive GO layers [16]. This interlayer distance can be suitably altered [17–19] to get the desired water permeation and salt rejection.

The highly selective nature of the GO membrane is mainly attributed to its unique structure [20]. The selectivity of the GO membrane is achieved by the size exclusion from the interlayer spacing, electrostatic interactions between the ions and the negatively charged GO nano-sheets, cation- $\pi$  interaction, metal coordination of the GO nano-sheet and among others. Based on the selectivity pertained to the size exclusion from the interlayer spacing in the layered GO membrane, molecules and ions can be separated according to their hydrated radius and ions with a hydrated radius  $> 4.5$  Å are not able to permeate through the GO membranes [21].

Recently a scalable production method for GO membrane has been addressed [22] that maintain large diameter graphene oxide flakes ( $> 100$   $\mu\text{m}$ ) with high oxygen-to- carbon ratios ( $> 40\%$ ). Similarly, a synthetic tree that incorporates a GO membrane has recently been designed [23] which allows water to be moved passively using the same mechanisms as terrestrial plants. GO can also be combined with other membrane materials to obtain homogeneous membrane matrix [24,25] for enhancement of membrane functionality. GO membrane possess several interesting advantages over existing commercially available membrane [26,27] e.g., lower membrane fabrication cost, simple and scalable synthesis procedure, high water permeability, exceptional selectivity among others. Another advantage of GO membrane is that in

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Nanofluidic transport through humic acid  
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The chemical similarity of graphene oxide (GO) and humic acid has been exploited to fine-tune the ionic and molecular transport properties of a lamellar GO membrane. Introduction of humic acid (in 10, 15 and 20%) is found to improve the nanofluidic transport characteristics, such as ionic mobility, molecular selectivity, diffusivity and permeability, of the GO membrane. Remarkably, the membrane prepared with 15% humic acid displayed superior proton mobility ( $\mu_{\text{H}^+} = 1.04 \times 10^{-4} \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1}$ ), in-plane diffusivity ( $D = 4.8 \times 10^{-6} \text{ cm}^2 \text{ s}^{-1}$ ), and cross-plane permeability ( $P_{\text{L}} = 2.03 \times 10^{-4} \text{ mm g cm}^{-2} \text{ s}^{-1} \text{ bar}^{-1}$ ) to the pure GO and other composite membranes. The favorable nanofluidic characteristics of the 15% membrane are attributed to the larger effective heights of the 2D nanochannels, derived from the onset point of the surface charge governed ionic conductivity of the membranes. The activation energy of proton transport ( $\sim 0.07$  to  $0.1 \text{ eV}$ ) confirmed the occurrence of a Grotthuss-like hopping mechanism in all the GO–HA membranes. Introduction of humic acid into two-dimensional GO channels also improved the solution stability and mechanical robustness of the pristine GO membrane. The lamellar GO–HA membranes were also found to be suitable for energy harvesting applications such as direct methanol fuel cells and reverse electrodialysis. Remarkably, even after 72 hours exposure to electrolyte solutions, open circuit potentials up to 0.05 V, 0.21 V, and 0.12 V were found for the 10, 15, and 20% membranes, respectively.

## Introduction

Fabrication of well-defined nanochannels in the sub-nanometer size regime is a matter of great importance as these channels provide access to interesting phenomena associated with biological nanochannels and promise technological breakthroughs in areas like water treatment, energy harvesting and molecular sieving.<sup>1–4</sup> The major bottleneck in the study of sub-nanometer-size fluids is the limitation in device fabrication techniques. The traditional methods employed for this purpose are either of low-throughput or require highly expensive and sophisticated instrumentation.<sup>5–7</sup> In order to overcome these shortcomings, molecularly thin nanochannels were prepared by self-assembling exfoliated layers of two-dimensional (2D) materials.<sup>8–14</sup> The space between the layers of reconstructed-layered-materials forms a

percolated network of two-dimensional nanochannels, providing a new platform to study ionic/molecular transport under sub-nanometer confinement. Thanks to the abundance of layered materials, and ease of preparation and scalability, reconstructed lamellar membranes also promise practical applications in areas like water desalination, molecular sieving, and energy storage and harvesting.<sup>15,16</sup>

Even though layered material based lamellar membranes have several advantages over polymer and inorganic membranes, they are not free from drawbacks. The sub-nanometer-size pores of lamellar membranes that facilitate unprecedented ionic/molecular selectivity also impede molecular permeability. The natural choice to overcome the problem of low permeability is to increase the channels' heights by applying spacers between the sheets.<sup>17–19</sup> However, application of incompatible inert spacers could sacrifice the selectivity and robustness of the pristine membranes. Here, we have explored the possibility of tuning the transport characteristics of GO membranes without sacrificing their lamellar structure or altering the channels' heights. Humic acid, a naturally occurring organic material, is applied here to tune the structure of GO nanochannels. With a structure chemically and physically similar to that of GO, humic acid causes an all-round improvement of the GO lamellar membrane.

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## Materials Science inc. Nanomaterials &amp; Polymers

## Non-Hydrothermal Synthesis of Cu(I)-Microleaves from Cu(II)-Nanorods

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Simultaneous transformation of structural morphology, material dimension and oxidation state of Cu(II)-nanorod was achieved with 3-(Triethoxysilyl)propylamine, (APTS) and 4-nitrobenzaldehyde (4-NB) under non-hydrothermal condition. Morphology of the modified Cu(I) material was found to resemble with the leaf of colocasea. Conversion of a Cu(II) based nano-material to a Cu(I)-based micro-material was confirmed from EPR, MAS-NMR and cyclic voltametric (CV) study. BET-surface area, Raman signal intensity and thermal stability of the Cu(I)-microleaf was greatly enhanced due to presence of Cu-O-Si linkage. Both the Cu(II) and Cu(I) material were found to be effective catalyst

systems for nitro-aldol reaction as well as catalytic oxidation of methylene blue (MB) dye in presence of H<sub>2</sub>O<sub>2</sub>. High %yield (> 90%) of nitro-aldol product was obtained with both the catalyst. Catalytic reaction under microwave irradiation was found to bring substantial decrease in reaction time. Cu(II)-material was however not recyclable because of its soft nature. While the Cu(I)-microleaf was recycled upto four consecutive cycles. These materials were found to degrade methylene blue dye within 20 min in presence of H<sub>2</sub>O<sub>2</sub> but in absence of light. Dark phase catalytic oxidation of MB was monitored both via UV-vis and cyclic voltametric study.

## Introduction

Development of nano-based materials and nanotechnology has recently brought a new renaissance in designing of newer materials for various applications.<sup>[1]</sup> Starting from its applications in house utensils to the drug delivery, nanomaterials have captured a wide range of research area like energy conversion and storage, chemical manufacturing, biological applications, and environmental technology.<sup>[2-12]</sup> Catalysis by nanoparticles or nanomaterials is one of the important aspects where researchers from both industries and academics are paying much interest.<sup>[14,15]</sup> So far various transition metal like gold (Au),<sup>[16]</sup> platinum (Pt),<sup>[17]</sup> palladium (Pd),<sup>[18]</sup> silver (Ag)<sup>[19]</sup> etc have been well explored as nanocatalyst for transforming various

organic reactions. In this context, Cu-containing nanomaterials or nanoparticles are gaining much interest in catalysis due to the high abundances of copper and low cost synthetic method. Cu-nanoparticles either in its oxide form CuO or as hydroxide, Cu(OH)<sub>2</sub> or as sulphides, CuS has recently been employed as catalyst in various type of catalytic reactions.<sup>[20]</sup>

Cu-nanomaterials or nanoparticles are mostly synthesized by hydrothermal or solvothermal methods using some suitable reducing and stabilizing agents.<sup>[20]</sup> In many cases Cu-salts with different counterions are taken as source of copper.<sup>[20]</sup> These methods however have some limitations i.e. control over the growth of nanoparticles. Temperature, pressure, molar ratios, nature of counterions and stabilizers plays vital role in architecting the surface morphology of Cu-nanomaterials.<sup>[21]</sup> So in recent years researchers are trying to synthesize Cu-based nanomaterials using some metal complex as precursors. Liu et al.<sup>[22]</sup> has synthesized CuS from Cu-thiourea complex, Yao et al.<sup>[23]</sup> has obtained CuS from Cu(I) complex of thioacetamide.

Researchers seemed to be more focused towards the hydrothermally synthesized Cu-nanomaterials in low oxidation state. But less emphasis has been given on synthesis of Cu(I) and Cu(II) material without following the conventional hydrothermal process. A very few reports are available for synthesis of Cu(II) complex in its nanodimension.<sup>[24,25]</sup> The objective of the present work is therefore to synthesize a Cu(II)- complex in nanoscale and its conversion to a Cu(I)-based material via a non-hydrothermal process. Such method will reduce the number of steps involved in hydrothermal process. It will also avoid the use of specific stabilizing agent and also the toxic reducing agents resulting in a development of one green method. Further, as one dimensional nanomaterials also finds high applications in optics, magnetism, and microsystems

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## PRESENT STATUS, CONSERVATION AND MANAGEMENT APPROACH OF WETLAND RESOURCES: A CASE STUDY OF SAMAGURI BEEL OF NAGAON DISTRICT, ASSAM

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### ABSTRACT

The Samaguri beel in Nagaon district of Assam occupies an important position among the wetlands of the district because of its unique environmental setting as well as its geo-physical characteristics. The beel is originate due to intense meandering process of the river Kokring which plays an immense role towards maintaining the ecological balance of the concerned area as well as to the livelihood of the people of adjacent villages. Due to over exploitation of the wetland resources, the ecological condition the wetland environment have been deteriorated day by day. Therefore, the present study is an approach to investigate the changing wetland status which have caused by natural and man-made factors and also identify the utilization pattern of wetland resources by the adjacent communities. This study is also emphasis upon to deliberate sound management policies to conserve the wetland environment.

**Keywords:** Wetland, resource, utility pattern, degradation, conservation

### Introduction

Wetland resources have significant functions and values for the human environment which determine the socio-economic development of wetland communities (Liu *et al.* 2004, Dagan, 1990, Silvious *et al.* 2000, Dixon, 2005). It is noteworthy that in developing countries significant portion of rural people primarily depend upon the use of wetland resources for sustaining their livelihoods which make a notable interdependence between wetland resources and their surrounding communities. Wetlands play a direct role towards the neighbouring communities by providing food, fuel and fiber to the local inhabitants. Besides these, wetlands support aqua culture, grazing and provide habitats for harvestable plant and animal species. Many of them become the source of drinking water for livestock and provide drainage and irrigation facilities for agricultural activities. In rural environment, wetland agriculture and fishing are considered as a major economic pursuit among the wetland dependent communities, as wetland areas are suitable for cultivation of a variety of crops and vegetables (Adams, 1993). The overexploitation of wetland resources as well as irrational land use patterns in marginal wetland areas have caused degradation of wetlands at an alarming rate which have great impact upon its bio-physical productivity. Therefore, there is a great need to make the concerned people aware towards the conservation and management of wetland resources. Although wetlands play an important role to livelihood security, but now a days, there is recognition of the need to integrate conservation and development of wetlands (McCartney *et al.* 2005). It is therefore, ensuring the sustainability of wetlands and their services are considered as a major concern for many organizations by promoting different conservation initiatives (Mahby 1986, Dixon 2005).

The riverine landscape of the state of Assam is mosaic of wetland resources which are characterized by varied shapes and sizes. It is however, important to note that wetlands and their resources considered as an integral parts of the livelihoods of the rural lives in Assam by providing different kind of services like farming, grazing, livestock rearing and traditional and commercial mode of fishing (Deka and Bhagabati, 2015). Hence, in present day context the wetland resources of the state have also been experiencing tremendous pressure and stresses from a wide range of socio-economic driving forces like population growth and agriculture mainly which lead the degradation process in the ecosystem (Balmford *et al.* 2002). Therefore, wetland conservation is an approach to manage the wetland resources, besides in order to mitigate the rate of degradation process in wetland areas as well as enhance their ecosystem services over time (Turner *et al.* 2003). The Samaguri beel of Nagaon district in Assam is one of the prominent ox-bow shape wetlands of the district faced big challenges in recent time which have emerged as a result of irrational developmental activities like construction of roads, railways, extension of settlement and also from farming practiced in marginal wetland areas. This paper is an attempt to study the present status of wetland resources and their utility pattern and changing scenario so as to formulate conservative plan and management strategies to restore the wetland ecosystem.

## LAND USE/LAND COVER CHANGES IN DIGHOLI BEEL OF KAMRUP DISTRICT, ASSAM

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### Abstract

Like other wetlands of Assam, the wetlands of Kamrup district also experience considerable shrinkages in their area. It is disheartening to note that the sizes of all the wetlands of the district have been decreasing over time, mainly because of the influence of many irrational anthropogenic activities. The wetlands of Kamrup district have been facing serious threat mainly from the ruthless anthropogenic activities. The irrational human interventions on the wetlands not only bring changes in their physical characteristics but also the functioning of the aquatic ecosystems. Wetlands play a significant role for regulating climate, providing water for people and cattle, supporting habitat for various aquatic plants and animals and also for providing livelihood to the people living around it. The Digholi beel is one of the important beels of Kamrup district which has its natural linkages with the river Brahmaputra. The present study is carried out in the Digholi beel of Kamrup district, Assam and is basically based on the satellite images collected from the Landsat images and IRS images.

**Key words:** Beel, fluvio-geomorphic characteristics, aquatic bio-diversity, livelihoods, changes.

### Introduction

Wetlands are the most important habitats of a large variety of plants and animals which contribute a range of goods and services to the concerned human society (Maltby, 1991; Aber, *et al.*, 2012). Being located in transition between terrestrial and aquatic ecosystems the wetlands are biologically the most productive ecosystems of the landscapes (Maltby, 2009; Keddy, 2010). However, very recently under the influence of many socio-economic and political factors the valley's wetlands have been facing a lot of problems. The increasing pressure on the wetland ecosystems caused by overpopulation, extension of agricultural lands to the marginal areas, rapid growth of human settlements, urbanization, industrialization, unscientific application of chemical pesticides and fertilizers on the agricultural fields, disposal of garbage and wastes have triggered serious threats to the aquatic biodiversity in the wetlands of the Brahmaputra valley. In Kamrup district of Assam the rate of degradation of wetlands is more as the processes of urbanization, industrialization and expansion of human settlement have been going on very rapidly in the district (Bhattacharya and Bhagabati, 2011). All most all the wetlands of the district are under threat and many of them have been disappearing (Sahariah and Bora, 2008). The degradation of wetlands in the district has not only caused many environmental crisis but also created many social and economic problems to the neighbouring communities. The Digholi beel of Kamrup district (Fig.1) is one of the important wetlands of the district which has very recently faced big challenges from the ruthless and irrational human activities in the name of so-called development.

### Study Area

Digholi beel is located between 91°39'10" E and 91°39'50" E longitude and 26°12'42" N and 26°14'20" North latitude. It is at an altitude of 168 feet above the mean sea level. This beel is located under Sualkuchi Development Block of Kamrup district. The beel is adjacent to the mighty river Brahmaputra and on the foothill region of Agyathuri hill. The total area covered by this wetland is 110 ha. The beel surrounded by north Malang hill and Sindurighopa village on its north, Pacharia Dalor Pathar and Pub Dadara on its west, Kalipahar and Sila Reserved forest on the east while the southern part is bordered by Dali Bari No. 1 and Agyathuri village.

## GEO-ECOLOGICAL STATUS, CONSERVATION AND MANAGEMENT OF THE HAHILA BEEL IN NAGAON DISTRICT, ASSAM

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**Abstract :** Like other ecosystems, wetlands are also confronted to a variety of deterrents leading to its premature degeneration. This paper is an attempt to examine the geo-ecological status of the Hahila beel in Nagaon district, Assam and also the factors responsible for degradation of the wetland so as to provide some measures for its conservation and eco-restoration. The changing land use pattern in the marginal wetland areas is contributing gradual shrinkage of wetland areas, creating a hurdle to otherwise sustainable wetland ecosystem. Expansion of agricultural activities, excessive use of chemical fertilizers, pesticides and insecticides are creating a condition of threat to the wetland biodiversity. The study has been carried out on the Hahila beel which is one of the prominent wetlands in Nagaon district of Assam. The local people have encroached wetland areas for sustaining their livelihood. These have resulted in dreadful conditions of wetland habitat and reduced the level of biodiversity. Therefore, a comprehensive study is very important to put forward some conservation and management practices.

**Key words:** Wetland, Geo-ecology, land use pattern, conservative plan.

### Introduction

Wetlands are considered as the most productive ecosystems in the world which provide resources and different kind of services to the concerned human society (Khan, *et al.*, 2009, Millennium Ecosystem, 2005). It is important to note that although wetlands constitute 6 percent of the earth surface but it has the ability to produce 24 percent of the primary production (Goldie, 2001). The ever increasing population and limited natural resources has become difficult

to make decision towards uncontroversial land use pattern (Katherine, 1990). Like any other natural entities wetlands have also been confronting growing pressure and threat from a variety of natural and man-made factors. During the recent period man-made factors have proved to be highly invasive and destructive towards the loss of wetland biodiversity. (Walker, *et al.*, 1987). It is noteworthy that the conversion of wetlands for agricultural purpose is considered as the principal cause of wetland degradation (Dahl, 2000). Since

## GEO-PHYSICAL CHARACTERISTICS OF WETLAND RESOURCES IN NAGAON DISTRICT, ASSAM

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**ABSTRACT :** This study is an attempt to identify the distribution of wetland resources and also investigate their origination, morphology and hydrological characteristics in floodplain region of Nagaon district, Assam. These wetland resources are popularly known as *beels* and besides swamps and marshes commonly known as *doba*, *hola*, *jalah*, *pitoni* and *doloni* among the local people of the district. The wetlands found in the district as various types and sizes cover an area of 9849.40 hectares accounting for 2.48% of the total geographical area of the district. It is identified that 65.63% of total wetlands are riverine origin and 34.37% constitute as waterlogged and man-made type. The fluvio-geomorphic process, soil texture and climatic condition as well as man-made factors have governed the existing wetland pattern in the district.

**KEYWORDS:** Wetland, Distribution and origin, Morphology, Hydrology

### 1. INTRODUCTION

Wetlands in geo-physical environment locate mainly interface between truly terrestrial and aquatic surfaces (Mitch and Gosselink, 1993), and saturated with water either permanently or seasonally and therefore, these characteristics instigate to make as a distinct ecosystem in the earth surface (Turner *et al.*, 2000, Schuyt and Brander, 2004). It is important to note that although wetlands constitute 6 percent of the earth surface but it has the ability to produce 24 percent of the primary production (Goldie, 2001). Wetlands are considered as the most productive ecosystems in the world which provide resources and different kinds of services to human society (Khan *et al.*, 2009, Millennium Ecosystem, 2005).

In developing countries significant portion of rural people depend upon the use of wetland resources for sustaining their livelihoods. The ecosystem services play an important role in maintaining the relationship between wetlands and their surrounding communities. In Assam, wetlands are mostly confined to the floodplain areas which are hydrologically connected to the nearby rivers and streams. Within the state, the highest number of wetlands are found in Nagaon district with a total number of 379 (ARSAC Report, 1997) and most of them are located in the agricultural environment. Wetlands play a direct role towards the neighbouring communities by providing food, fuel and fiber to the local inhabitants.

The wetlands of Nagaon district are showing typical physical characteristics in respect of their distributional pattern, morphological characteristics, hydrological characteristics and biodiversity of wetland resources due to diverse physio-climatic setting of the district. The wetlands of the district are endowed with varied shape, size and origin and these are mainly influenced by their topographic regime, diverse fluvial process as well as variation in climatic condition within the district. The riverine landscape of the district is provided favorable condition to formation of numerous wetlands in the district. The wetlands in the district which are resemble with lake like water bodies locally known as *beel* and on the other hand swamp and marshy areas are termed as *doba*, *hola*, *jalah*, *pitoni* and *doloni* etc (Sharma, 1994). It is worth mentioning that the depth of swampy and marshy type of wetland normally shallower than the natural lake like *beels*. Most of the wetlands in the district are riverine origin and it has maintained a hydrological connectivity with nearby rivers and streams through a narrow channel which is locally known as *jau*. On the other hand many wetlands have completely lost their connectivity with rivers and turn into close wetland due to perform several developmental activities most commonly by agriculture. These connecting channels of wetland play important role towards maintaining the hydrological dynamism and ecological perspective of wetland resources. The water levels and its flowing pattern of wetlands are showing in dynamic nature (Kulser, *et al.*, 1994) and which is considered as an integral part of wetland ecology.

## The Chandubi Beel Of Kamrup District, Assam : Present Status And Change

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### ABSTRACT

The Chandubi beel in Kamrup district of Assam occupies an important position in the wetland environment of the state because of its unique geo-ecological characteristics. This beel, which originated after the 1897's great earthquake, has been contributing immense role towards maintain the ecological balance of the concerned area as well as to the life and livelihood of the people of the neighbouring villages of the beel. However, with the changing environmental conditions and alarming rate of human dependency on the beels, the geo-ecological characteristics of the beel have been deteriorating. The present study, therefore, is an attempt to analyse the recent status of the beel and its changing geo-ecological characteristics over time caused by natural and anthropogenic factors. The study is based on personal field observation and investigation with the help of primary and secondary data collected from the field and the laboratory test of water and soil parameters. The change in size of the beel has been analysed taking help of toposheets of Sol and satellite image of different years.

**KEYWORDS :** Chandubi beel, changing environmental conditions, human dependency

### INTRODUCTION

Wetlands are the most important component of fluvio-geomorphic landscape of a region which perform as transitional habitats between the terrestrial and aquatic ecosystems. Wetlands are an essential fraction of human civilization, meeting many crucial needs for life. Wetland plays a significant role in regional ecosystem, such as the regulation of climate, cleansing of environment and balancing of regional water. The wetland provides critical habitat for a large number of flora and fauna. (Keddy, 2010, Deka and Bhagabati, 2015). Being endowed with a large variety of floral and faunal species and naturally being static water body the wetlands of a region become ecologically very rich on the one hand and sensitive habitats on the other hand. It is noteworthy that earlier the wetlands of the State of Assam were considered as wastelands as they were not used for productive purposes. However, after the 2<sup>nd</sup> half of the 20<sup>th</sup> century many ecologists, geographers and environmental scientists have been giving importance on the wetland studies keeping in view of their multiple ecological, physical and economic functions to the concerned areas (Barbier, Acreman and Knowler, 1997). All most all the wetlands of the district are under threat and many of them have been disappearing (Sahariah and Bora, 2008). The degradation of wetlands in the district has not only caused many environmental crises but also created many social and economic problems to the neighbouring communities. The Chandubi beel of Kamrup district (Fig.1) is one of the important wetlands of the district which has very recently faced big challenges from the ruthless and irrational human activities in the name of so-called development. The beel, once endowed with a wide variety of floral and faunal

## PRESENT STATUS, CONSERVATION AND MANAGEMENT APPROACH OF WETLAND RESOURCES: A CASE STUDY OF SAMAGURI BEEL OF NAGAON DISTRICT, ASSAM

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### ABSTRACT

The Samaguri Beel in Nagaon district of Assam occupies an important position among the wetlands of the district because of its unique environmental setting as well as its geo-physical characteristics. The beel is originate due to intense meandering process of the river Nokong which plays an immense role towards maintaining the ecological balance of the concerned area as well as to the livelihood of the people of adjacent villages. Due to over exploitation of the wetland resources, the ecological condition the wetland environment have been deteriorated day by day. Therefore, the present study is an approach to investigate the changing wetland status which have caused by natural and man-made factors and also identify the utilization pattern of wetland resources by the adjacent communities. This study is also emphasis upon to deliberate sound management policies to conserve the wetland environment.

**Keywords:** Wetland, resource, utility pattern, degradation, conservation.

### Introduction

Wetland resources have significant functions and values for the human environment which determine the socio-economic development of wetland communities (Liu *et al.* 2004, Dagan, 1990, Silvious *et al.*, 2000, Dixon, 2005). It is noteworthy that in developing countries significant portion of rural people primarily depend upon the use of wetland resources for sustaining their livelihoods which make a notable interdependence between wetland resources and their surrounding communities. Wetlands play a direct role towards the neighbouring communities by providing food, fuel and fiber to the local inhabitants. Besides these, wetlands support aqua culture, grazing and provide habitats for harvestable plant and animal species. Many of them become the source of drinking water for livestock and provide drainage and irrigation facilities for agricultural activities. In rural environment, wetland agriculture and fishing are considered as a major economic pursuit among the wetland dependent communities, as wetland areas are suitable for cultivation of a variety of crops and vegetables (Adams, 1993). The overexploitation of wetland resources as well as irrational land use patterns in marginal wetland areas have caused degradation of wetlands at an alarming rate which have great impact upon its bio-physical productivity. Therefore, there is a great need to make the concerned people aware towards the conservation and management of wetland resources. Although wetlands play an important role to livelihood security, but now a days, there is recognition of the need to integrate conservation and development of wetlands (McCartney *et al.* 2005). It is therefore, ensuring the sustainability of wetlands and their services are considered as a major concern for many organizations by promoting different conservation initiatives (Maltby 1986, Dixon 2005).

The riverine landscape of the state of Assam is mosaic of wetland resources which are characterized by varied shapes and sizes. It is however, important to note that wetlands and their resources considered as an integral parts of the livelihoods of the rural lives in Assam by providing different kind of services like farming, grazing, livestock rearing and traditional and commercial mode of fishing (Deka and Bhagabati, 2015). Hence, in present day context the wetland resources of the state have also been experiencing tremendous pressure and stresses from a wide range of socio-economic driving forces like population growth and agriculture mainly which lead the degradation process in the ecosystem (Balmford *et al.* 2002). Therefore, wetland conservation is an approach to manage the wetland resources, besides in order to mitigate the rate of degradation process in wetland areas as well as enhance their ecosystem services over time (Turner *et al.* 2003). The Samaguri beel of Nagaon district in Assam is one of the prominent ox-bow shape wetlands of the district faced big challenges in recent time which have emerged as a result of irrational developmental activities like construction of roads, railways, extension of settlement and also from farming practiced in marginal wetland areas. This paper is an attempt to study the present status of wetland resources and their utility pattern and changing scenario so as to formulate conservative plan and management strategies to restore the wetland ecosystem.



AGRICULTURAL LANDUSE PATTERN OF NAGAON DISTRICT,  
ASSAM: PRESENT STATUS AND CHANGING SCENARIO

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Banashree Saikia<sup>1</sup>, D. Sahariah<sup>2</sup>: Agricultural Landuse Pattern of Nagaon District, Assam: Present Status and Changing Scenario-- Palarch's Journal Of Archaeology Of Egypt/Egyptology 17(7). ISSN 1567-214X  
Keywords: Agriculture, landuse, cropping pattern

**ABSTRACT**

Agricultural landuse pattern of the district is mainly influenced by the fertile plain along with favourable climatic condition of the region which permits to cultivate different varieties of crops in different season. Rice, wheat, pulses, sugarcane, spices, fruits and vegetables, different oilseeds (rape and mustard, sesame) and jute etc. are extensively cultivated all over the district. The various socio-economic factors are also responsible for producing diverse agricultural land use pattern in the district. As agriculture is considered as a primary economic activity to sustain their livelihood of rural people, therefore cultivation of different varieties of crops produce diverse landuse pattern in the district. This study is an attempt to identify the intra-district variation in agricultural cropping patten and their spatio-temporal changes over time.

**Introduction**

In Nagaon district of Assam, agriculture and its allied activities played an important role in the socio-economic development as this sector is considered as a major contributor towards the district economy. Agriculture is considered the backbone of rural economy of the district as it provides livelihoods of rural people.

In Assam, generally agricultural land use means the cultivation of soil for growing crops to fulfill the human needs only (Das, 1984). Agricultural land use of Nagaon district is shown by cultivation of different crops like rice, wheat, pulses, sugarcane, spices, fruits and vegetables, different oilseeds (rape and mustard, sesame) and jute etc. which are extensively cultivated all over the district. In agricultural land use pattern of Nagaon district, a significant spatio-temporal variation is observed during 2005-2017 at revenue circle level. The diverse geo-ecological set-up associated with various socio-economic factors has responsible for producing diverse agricultural land use pattern in the district (Bhagabati, 1990). It has been seen

## LAND USE/LAND COVER CHANGES IN DIGHOLI BEEL OF KAMRUP DISTRICT, ASSAM

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### Abstract

Like other wetlands of Assam, the wetlands of Kamrup district also experience considerable shrinkages in their area. It is disheartening to note that the sizes of all the wetlands of the district have been decreasing over time, mainly because of the influence of many irrational anthropogenic activities. The wetlands of Kamrup district have been facing serious threat mainly from the ruthless anthropogenic activities. The irrational human interventions on the wetlands not only bring changes in their physical characteristics but also the functioning of the aquatic ecosystems. Wetlands play a significant role for regulating climate, providing water for people and cattle, supporting habitat for various aquatic plants and animals and also for providing livelihood to the people living around it. The Digholi beel is one of the important beels of Kamrup district which has its natural linkages with the river Brahmaputra. The present study is carried out in the Digholi beel of Kamrup district, Assam and is basically based on the satellite images collected from the Landsat images and IRS images.

**Key words:** Beel, fluvio-geomorphic characteristics, aquatic bio-diversity, livelihoods, changes.

### Introduction

Wetlands are the most important habitats of a large variety of plants and animals which contribute a range of goods and services to the concerned human society (Maltby, 1991; Aber, *et al.*, 2012). Being located in transition between terrestrial and aquatic ecosystems the wetlands are biologically the most productive ecosystems of the landscapes (Maltby, 2009; Keddy, 2010). However, very recently under the influence of many socio-economic and political factors the valley's wetlands have been facing a lot of problems. The increasing pressure on the wetland ecosystems caused by overpopulation, extension of agricultural lands to the marginal areas, rapid growth of human settlements, urbanization, industrialization, unscientific application of chemical pesticides and fertilizers on the agricultural fields, disposal of garbage and wastes have triggered serious threats to the aquatic biodiversity in the wetlands of the Brahmaputra valley. In Kamrup district of Assam the rate of degradation of wetlands is more as the processes of urbanization, industrialization and expansion of human settlement have been going on very rapidly in the district (Bhattacharya and Bhagabati, 2011). All most all the wetlands of the district are under threat and many of them have been disappearing (Sahariah and Bora, 2008). The degradation of wetlands in the district has not only caused many environmental crisis but also created many social and economic problems to the neighbouring communities. The Digholi beel of Kamrup district (Fig.1) is one of the important wetlands of the district which has very recently faced big challenges from the ruthless and irrational human activities in the name of so-called development.

### Study Area

Digholi beel is located between 91°39'10" E and 91°39'50" E longitude and 26°12'42" N and 26°14'20" North latitude. It is at an altitude of 168 feet above the mean sea level. This beel is located under Sualkuchi Development Block of Kamrup district. The beel is adjacent to the mighty river Brahmaputra and on the foothill region of Agyathuri hill. The total area covered by this wetland is 110 ha. The beel surrounded by north Malang hill and Sindurighopa village on its north, Pacharia Dalor Pathar and Pub Dadara on its west, Kalipahar and Sila Reserved forest on the east while the southern part is bordered by Dali Bari No. 1 and Agyathuri village.

(4) Pinaki Kumar Rabha (Department of Botany)

## Monitoring of land use and land cover changes of Kapla beel, a major wetland of Barpeta district, Assam using multi temporal satellite data

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### ABSTRACT

*Kapla beel is a perennial freshwater wetland of Barpeta district of Assam, India situated at the global position between 26°18' 12" N to 26° 25' 7" N latitude and 91° 08' 42" E to 91° 14' 50" E longitude. The present investigation reveals that the wetland of the present study site has degraded or is under the stress of different environmental factors because of various natural as well as anthropogenic activities occurring over the last few decades. Land use and land cover change is a useful tool for determining the ecological degradation of wetland which is under the pressure of several natural as well as man-made activities. The present study has been carried out to delineate the changes of Kapla beel of Barpeta district, Assam using LANDSAT TM data. The results of the present study reveal that the water spread areas of Kapla beel is reduced by 50.3% and 45.5% in pre-monsoon and post monsoon season respectively during the year 1987 to 2013. It is mainly due to encroachment inside the wetland area for different developmental activities. Besides the construction of dykes surrounding the beel has caused formation of heavy detritus due to gradual death and decay of aquatic macrophytes inside the wetland areas which ultimately make the wetland very shallow. Therefore proper restoration measures of this important wetland of the district is the need of honor for the sustainable existence of the wetland and also livelihood of the poor people living in its vicinities.*

**Key words:** Kapla beel, anthropogenic activities, land use and land cover change, LANDSAT TM data and restoration measures.

### INTRODUCTION

Wetlands are the highly fragile ecosystem of the world. Wetland plays a significant role in regional ecosystem, such as the regulation of climate, cleansing of environment and balancing of regional water and provides suitable habitat for aquatic flora and fauna. Based on several estimates, the extent of the world's wetlands is generally thought to be from 7 to 9 million km<sup>2</sup>, or about 4 to 6 percent of the land surface of the earth<sup>17</sup>.

It has also been estimated that 20 % of the known range of biodiversity in India are supported by freshwater wetlands<sup>4</sup>. However in recent years, anthropogenic activities such as urban development and agricultural management have caused a significant change in the land use-land cover and subsequent loss of wetland<sup>20</sup>.

Landscapes are not static, there are numerous exogenous and endogenous forces continuously operating over the landscapes and because of this landscapes are dynamic in nature. All over the world ecosystems have been rapidly transformed in the post-2000 period by human populations through increasingly permanent uses of land<sup>8</sup>. Land-use/land-cover (LULC) change is of much interest in environmental

## TRADITIONAL BONE SETTING PRACTICE OF RABHA PEOPLE OF ASSAM

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## ABSTRACT

**Objective:** The aim of this work is to document the various ethnomedicinal healing plant species used in traditional bone setting (TBS) practice of Rabha community of Assam.**Methods:** This has been done using interview method which includes semi-structured questionnaire and the field walks method.**Results:** The results reveal that eight healing plants were employed to in the TBS practice. Among these, *Cissus quadrangularis* L. is the most commonly used plant species to treat bone fracture. In this study, two modes of preparation for the ethnomedicine have been served (i.e., paste and extract) where paste form has higher used (75%).**Conclusions:** It has been concluded that Rabha Hasong area of Assam is indeed rich in ethnomedicinal plants. People get benefited from the traditional practices performed by the medicine men. This is the chief reason TBS practice that is still running smoothly with full faith and hope even in the current time where sophisticated orthopedic treatments are obtainable. Moreover, systematic nutraceutical appraisal of these species would provide a remarkable research possibility in the fields of ethnopharmacology that would be useful in the modern orthopedic treatments.**Keywords:** Ethnomedicine, Rabha Hasong autonomous council area, Rabha tribe, Traditional bone setting practice.© 2019 The Authors. Published by Innovare Academic Sciences Pvt Ltd. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>) DOI: <http://dx.doi.org/10.22159/ajpcr.2019.v12i1.28671>

## INTRODUCTION

Ethnomedicinal practices are still unable to catch enough patronage by the laypeople of India. These have diverse biological efficiencies that contribute to pharmacological research and food industries [1-3]. A large number of ethnic communities are dwelling in India which are blessed with significant and diverse sociocultural and ethnic identities [4]. Each community has a unique grip of traditional belief and wise practice for health necessities. Therapeutic herbs play an inimitable role in this traditional knowledge system which is practiced and equally benefited by a remarkable number of folks [5,6]. Something like 70,000 bone setters in India are engaged in traditional bone setting (TBS) practice. They are practicing it without any principles of modern orthopedics study and other traditional practices such as Ayurveda, Homeopathy, and Unani but using their own methodology and ideas. Moreover, the treatment process of TBS practice has commenced without any prediagnosis of the disorder like X-ray evaluation. Therefore, this is considered one of the noteworthy traditional practices of India. This has been practiced widely in different parts of India such as Tamil Nadu, Andhra Pradesh, Kerala, Karnataka, Assam, and West Bengal [7-9].

The Rabha Hasong Autonomous Council area located in between 25° 53' and 26° 49' N latitude and 90° 07' and 91° 50' E longitude. It has an area of 3161<sup>1</sup> km covering two districts with 823 villages. Among Schedule Tribe, Rabha, Bodo, Garo, and Hajong people are dwelling in that area.

The Rabha people are maintaining their traditional distinctiveness of sociocultural fabrics with characteristics religious belief and practices, festivals, language, culture, etc. Beyond Assam, they are found in Meghalaya, Manipur, West Bengal, and even in two neighboring countries, Nepal and Bangladesh. In Assam, they are mostly distributed in Kamrup and Goalpara district (called Rabha Hasong Autonomous Council) and few patches of Darrang district [10]. Rabha tribe has nine subtribes with individual dialect and customs. These are - Rangdani, Maitori, Pati, Dahuri, Koch, Hama, Tolta, Bitliya, and Shonga.

Bone is the unbend organ which is the great support and guard of the skeleton that provides proper strength to the vertebrate body. Unfortunately, due to some accidental incidents, it may cause severe bone fracture. Most of them have less interest toward the painful modern orthopedic treatments. Interestingly, some ethnic communities involve in TBS practice those provide a great relief and hope to the sufferer. The current work is, therefore, formulated to unveil some healing plants used by the "traditional bone setter" of Rabha tribe in their TBS practice.

## Study site

The present study site comprises four places of Kamrup district, Rani, Hazipara, Dakiapara, and Langkona and two of Goalpara district, Rongjuli and Dhupdhara (Fig. 1).

## METHODS

A survey has been carried out during the months from July to December 2017. Information was gathered from traditional bone setters who have a good knowledge of the utilization of plants as herbal medicine. The Rabha people of those areas are influenced by Assamese culture as well as language, thus no interpreters were employed. Interviews were followed by the standard method of Martin [11] and Maundu [12] which were semi-structured questionnaire and the field walks method. Information for the TBS practice has been included the name of the plant, part of the plant being used, form of the medicine, preparation processes of medicine, etc. The specimens were collected along with its reproductive parts for their appropriate identification. Photographs were also obliging that were captured in a natural habitat. The list of the ethnomedicinal plant names along with their local names, family names, used plant parts, voucher numbers, and medicinal uses has been presented in tabular form (Table 1). The collected specimens were preserved in the Department of Botany, J. N. College, Boko, Assam.

## RESULTS AND DISCUSSION

The present study has unveiled total eight healing plants from eight different families for TBS practice. Among these, only *Cissus*

## Structure, Above Ground Biomass and Carbon Stocks in a Sal (*Shorea robusta* Gaertn. f.) Forest of Goalpara District, Assam

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**Abstract** Sal forests generally have very low species. Two hectare of secondary Sal forest was intensively studied to assess the structure, AGB and C stock of Goalpara district, Assam. Only three species were recorded and *Shorea robusta* was totally dominated in both the study sites. Density and basal area of trees were ranges from 127–334 tree ha<sup>-1</sup> and 10.7–21.6 m<sup>2</sup> ha<sup>-1</sup>. Above ground biomass was recorded as 162.97 Mg ha<sup>-1</sup> and 92.91 Mg ha<sup>-1</sup> in Site-I and Site-II respectively. The study highlighted the structure, carbon storage and anthropogenic disturbances in Sal forests.

**Keywords** Regeneration, Anthropogenic disturbances, Rangjuli reserve forest, Sal forest.

### Introduction

Forests are being considered as one option for stabilising or reducing atmospheric carbon dioxide

by storing carbon in biomass, soils and its products. Tropical forests can store approximately 40% of terrestrial carbon [1] but when disturbed it release more CO<sub>2</sub> [2]. Estimations of above ground biomass play significant role in studying of carbon stocks, effect of deforestation and carbon sequestration on the global carbon balance [3]. The most reliable technique for estimating carbon stocks is through forest inventories followed by allometric relationships between the above ground biomass of a tree and its trunk diameter [4, 5].

Sal (*Shorea robusta* Gaertn. f.) is a semi-deciduous, light demanding tree that grows up to 45 m in height and frequently forms a mono-specific canopy [6]. In India Sal forests are spread over an estimated area of 10 million hectares [7]. Sal forests are typically categorized as Tropical Moist Deciduous Forest which in Assam can be further divided into Khasi Hill Sal forest (3CC1 1a (ii)) and Kamrup Sal forest (3C/C2 2d (iv)) [8]. The Sal forests of Goalpara district is part of "Kamrup Sal forest". Ahmed and Medhi [9] estimated that there was shrinkage of 1050.46 hectares reserve forests and proposed reserve forests areas of Goalpara district during the period 1981–2002 due to encroachment for human habitation, pasture and agricultural uses. Chitale and Behera [7] stated that moisture is one of the key factor that can influenced to shift distribution of Sal forests towards northern and eastern India due to changing climate. The present study provides important information on the structure, composition and carbon stocks with

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## Diversity of aquatic macrophytes of Kapla beel (wetland) of Barpeta district, Assam, India

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### ABSTRACT

The present study was conducted in Kapla beel to evaluate the macrophytic diversity of the wetland for a period of one year i.e. from October, 2013 to September, 2014. Kapla beel is a perennial freshwater wetland located at Barpeta district of western Assam at the global position between 26° 15' N to 26° 30' N latitude and 91° 0' E to 91° 15' E longitude. It covers an area of 91 hectares. Aquatic macrophytes were collected by using the methods as described by Raunkaier, (1934). During the present investigation total of 68 plant species belonging to 49 genus and 28 families were recorded from the wetland of the study site. The dominant family was Cyperaceae representing 12 species. Different diversity indices like Shannon-Weaver diversity index (Shannon and Weaver, 1964), Simpson diversity index (Simpson, 1949), Menhinick diversity index (Menhinick, 1965) and Concentration of dominance (Simpson, 1949) were calculated to show the plant communities structure of the wetland. Maximum values of Shannon-Weaver diversity index, Simpson diversity index and Menhinick diversity index were found during the summer season as it is active growth period of macrophytes whereas maximum concentration of dominance during the summer season reflects the dominance of few species due to high diversity of the macrophytes.

**Key words:** Wetland, Kapla beel, macrophytic diversity, diversity indices.

### INTRODUCTION

Wetlands represent a combination of aquatic and terrestrial environment, in which the soil is seasonally or permanently covered by shallow water and the water table is close to or near the surface [1, 2]. The freshwater, perennial, large, lentic water bodies are commonly known as 'beel' in Assam [3]. The aquatic macrophytes are the important source of food, fodder, herbal medicine and domestic household materials. Macrophytes, as a component of freshwater ecosystems play an important role in the structure and functioning of the aquatic ecosystems [4, 5]. Water plants, including macrophytes are universally recognized as important participants in the natural processes of water self-purification [6, 7].

Macrophytes also play a major role in primary productivity of the aquatic ecosystem. Aquatic macrophytes use nutrient from the aquatic environment and thus influence water quality. It also controls water quality by exuding various organic and mineral components but also act as an efficient accumulator of heavy metals [8, 9].

On a large scale, anthropogenic activities influence physical, chemical and biological processes of aquatic ecosystem and thereby causing decline and degradation of ecosystem services and also economic value of the wetland [10]. On the contrary, aquatic communities also reflect anthropogenic influence and are very useful to detect and assess human impacts [11]. Two factors i.e. number of species and importance values (number, biomass, productivity, and so on) of individuals, determine the species diversity of a community [12].



## SWOT Analysis of Teacher Education Programme: A Students Perspective

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**Abstract:** A programme development process can have encouraging results when it begins with “early assessment” that addresses different dimensions related with it. This paper presents a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis for Teacher Education Programme in Tezpur University with respect to various dimensions. A SWOT analysis is used to initiate meaningful change in a programme of study and to use the data for programme improvement. Descriptive method was adopted for the present study in which survey is the technique used. Considering the nature of the study, which is both qualitative and quantitative in its approach, purposive sampling technique was employed. The sample includes 100 teacher trainees. The tool used for the study is a self-developed questionnaire for student teachers to measure their perceptions regarding various dimensions of the programme. The collected data were subjected to analysis employing descriptive statistics such as percentage, mean and standard deviation. On the basis of analysis of data, the major strengths, weaknesses, opportunities and threats of the teacher education programme were identified.

**Keywords:** Teacher Education Programme, SWOT analysis

### 1. Introduction

Education is the most powerful instrument to combat most of the social evils that exists around the world. Education is a process of shaping the minds of the people towards socially acceptable goals that would also enrich the individual's life. The policy planners develop various plans and put forward various recommendations which sought to usher betterment in the society through the learners at all levels of education viz. primary, secondary and higher education. However, the vision and the mission of such highly placed educational plans and policies lay greatly, if not solely, in the gracious hands of the teachers as it is only the teachers that come in direct contact with the students in the classrooms. Also, the traditional role of a teacher which basically was ‘impartor of knowledge’ has been taken over by the contemporary role of a 21<sup>st</sup> century teacher which is ‘interpreter of knowledge’. Here comes the necessity of a sound teacher education programme.

Teacher educators, and national policies that provide a configuration to the teaching profession, are both very much critical for the provision of a good quality education, as teachers of the present era are taken as the pivotal facilitators of learning. Teachers are the largest professional group engaged in human development activities. Notwithstanding, it is a challenge for

education systems to pay adequate attention to factors affecting teacher effectiveness, such as policies on training, recruitment, deployment, management, assessment and professional development. Teachers often suffer from poor professional status, wages and work conditions. Moreover, an acute shortage of qualified teachers is also seen as an existing problem.

### 2. Concept of SWOT analysis & teacher education Programme

#### A. SWOT Analysis

It is a tool largely used in management and administration to find out the strengths and weaknesses as well as to estimate the probable opportunities and threats of any particular institute or programme or any business plan. Many people wrongly assume a SWOT analysis is only relevant for businesses, but it can be invaluable for individuals, organizations and even for team building. It is a strategic planning tool that thoroughly examines the internal strengths and weaknesses as well as external opportunities and threats.

#### B. Teacher Education Programme

It refers to the complete set of policies and activities needed to be acquired by a prospective teacher in order to attain proficiency and competency in the field of teaching. Such programmes need some entry qualification and on the completion of it, the candidature gains eligibility to be in the teaching profession.

Teacher education as a programme of study comprises of the policies, procedures, and provision designed to furnish student teachers with the knowledge, attitudes, behaviors, and skills which they require in order to perform their tasks effectively in the classroom, school, and wider community. The professionals who are engaged in this activity are called teacher educators. Traditionally, teacher education was called as teacher training, however it has been renamed rightly because training is provided for routine and mechanized tasks and teaching can in no way be a mechanized activity because here, a teacher constantly deals with various types of learning environments with students having individual differences with respect to their intellectual abilities, interests, aptitude, etc. therefore, the teacher education programme is more relatable with the preparation of staff for the role of a reflective practitioner.

(6) Bapukan Saikia (Department of political science)

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**Problems and Prospects of Small Tea Growers of Assam: A Brief Study**  
**Anamika Adhikari<sup>1</sup> Bapukan Saikia<sup>2</sup>**

**Abstract**

The tea plant was discovered in 1823 by Robert Bruce in Assam. Now Assam is the largest tea producer state of India contributing about 55% to India's total tea production and have given job opportunities to more than 10 lakh people of Assam. The tea gardens are located mostly in the rural areas of Assam. Though the tea plantation has a long history in Assam, the history of small tea growers is quite a new. Due to various reasons, the agriculture sector of Assam was underdeveloped and subsistence in nature. This compelled the agricultural land owners to think for an alternative cultivation. Tea plantation holding small size of land became one of the alternatives to sustain the livelihood as tea plantation provides work and income together throughout the year. Small tea growers have become an economic force for Assam which is started by the local entrepreneurs of Assam with local knowledge and experience. In this paper, we have analysed the history, problems and prospects of the small tea growers of Assam and also the role of government of Assam on encouraging the small tea growers or the local entrepreneurs.

**Keywords:** Assam, Tea, Plantation, Small Tea Growers, Rural

**Introduction**

More than 35 countries in the world produce tea and India is one of the major tea exporter countries. Tea industry in India is one of the oldest industries and this industry enjoys the status of one of the best organised industries in the country. Tea plantations in India are mainly located in North Eastern and Southern states. The major tea growing areas in India are concentrated in Assam, West Bengal, Tamil Nadu and Kerala. The other tea growing areas are Karnataka, Tripura, Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, Meghalaya, Nagaland, Manipur, Mizoram and Bihar.

Being one of the major tea-producing states of India, tea industry of Assam has been substantially contributing to its economy. Assam has over 10 lakh tea workers in organised sector working in 850 tea estates<sup>3</sup>. Tea plantation industry which is an agriculture-based industry occupies an important place in Assam and here, tea is grown both in the Brahmaputra as well as in the Barak Valley. Tinsukia, Dibrugarh, Sivasagar, Jorhat, Golaghat, Nagaon, Sonitpur and also the newly created Biswanath are the districts where tea gardens are mostly found<sup>4</sup>.

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<sup>3</sup> Bikash Singh, "Feel the plight of the tea workers and revise the min. wages to Rs 350 per day: ACMS to PM Modi", *Economic Times*, 29<sup>th</sup> Dec, 2018

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# WOMEN IN NATIONAL POLITICS: A STUDY FROM ASSAM

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**Abstract-** Women constitute half of the population around the globe but when it comes to representation of women particularly in politics, women lag far behind than that of men. Participation in politics or we can say political participation including men and women is the essence for the success of democracy. India, as the largest democratic nation, should encourage women to increase their political participation be it as the voters or as political representatives. In this paper, we have discussed the role and participation of women in national politics of India in general and women of Assam in particular and has focused on the need for reservation as the only way out to bring more women to politics.

**Keywords –** Women, Participation, National, Politics, Election

## I. INTRODUCTION

When we talk about women in politics, it simply defines political participation of women. Political participation means not only exercising the right to vote, but also active involvement in the decision-making process at all the levels of governance.<sup>1</sup> The International Encyclopaedia of Social Sciences defines political participation as the principal means by which consent is granted or withdrawn in a democracy and rulers are made accountable to the ruled. It signifies proceedings like voting, seeking information, discussing and proselytizing, attending meetings, contributing financially and communicating with representatives etc. The term 'political participation' has a very wide meaning. It is not only related to 'Right to Vote', but simultaneously relates to participation in: decision-making process, political activism, political consciousness, etc.

For the success of democracy, participation of the people both men and women are an essential ingredient.<sup>2</sup> As women comprise about half of the population, this section of society requires due attention in the system and a due share in the process.<sup>3</sup> Democracy will fail in its objectives if women citizens lack equal opportunity to participate in the governmental decision-making process. There cannot be a real democracy if the voices and issues of women are ignored or even side-lined.<sup>4</sup>

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## **RELIGIOUS ADAPTATION: A CASE OF TIWA IN THE RURAL CONTEXT OF ASSAM**

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### **Introduction**

Culture, a uniquely human attribute, is something which man interposes between himself and his environment in order to ensure his security and survival. As such culture is adaptive. On the other hand, adaptation may be defined as the process, in which changes in an organism, system of organization, personality of an individual and group or culture occur to become suitable to the new conditions or needs. The adaptive process of man is largely cultural not only genetic. Human group adapts to the environment by means of culture. Culture is adaptive both to its physical and social environment, which may change due to changes in the demographic pattern, change of habitat, etc. Human beings adapt to their environment by means of technological, organizational, and ideational adaptation. In this paper an attempt has been made by the investigator to study the adaptation that has been observed in the field religion among the Tiwas of Bargaon village of Kamrup district, Assam. The objectives of the paper is to examine how the people of the study village adapt to their culture, specially in the fields of their religious life, how some beliefs and customs become integral part of their life. Here an attempt has also been made to study the forces and causes responsible for these changes and adaptation.

Human groups adapt to their environment by means of their culture. Environment means both social and natural environment (Swaminathan, 1960). Man's social and cultural adaptability refers to the objectivity or goal for which a man works and the mechanism through which adaptation through the situation are acquired (Mahanta, 1987:44-45). Adaptation makes possible one's survival in the new environment. Some individuals or groups may acculturate or assimilate to the new culture. When the individuals go through the assimilation process, they adopt the new culture as their own, replacing the old cultural beliefs, attitude and behaviours. But sometimes they may even begin to make identity with both cultures.

### **The Tiwa**

The Tiwas are one of the prominent scheduled tribes of Assam. They are chiefly residing in the district of Nagaon although some of them are scattered in the hills and the plains of Karbi Anglong, Kamrup, Darrang, Dhemaji and Lakhimpur districts of Assam (Baruah, 1989:1). The Tiwas are popularly known as Lalungs but at present they prefer to call themselves as Tiwa. The name Lalung, they opine

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