Science of Eastern Himalaya Journal 1(2):16-23. 2022 ISSN 2583-4169

Fragile Mountain System of Sikkim

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[Received 23 July, 2022; Revised 12 November, 2022; Accepted 22 December, 2022; Published 22 December, 2022]

Abstract

Mountain ecology of Sikkim Himalaya is the fragile ecosystem that depends on the different landforms, wetlands, lakes, rivers, flora and fauna. The landforms, especially hilly areas, are on the convergent boundaries of tectonic plates having numerous lakes, wetlands, hot spring, calderas etc. These wetlands are the strength of the mountain ecology of Sikkim.

The fault lines and the crevices of the earth play a pivot role in the water sources as well as wetlands in the hilly areas for recharging the groundwater. The interference in the earth crust may disrupt the fault lines or the crevices etc of the earth crust resulting aridness and ecologically imbalance in the region.

Thus, the data of the high elevated North-Eastern part of Sikkim's wetlands and the low elevated Tendong Reserve Forest data are presented to interpret the dependence of the wetland and water sources for the maintenance of the mountain ecosystem.

Keywords: Groundwater, Mountain ecology, Sikkim Himalaya, Water Table

Introduction

The mountain ecology of the hills of Sikkim Himalaya lies on the convergent boundaries of Indian tectonic plate and Eurasian tectonic plate. The fault lines of the tectonic plates, crevices, neck etc are pivotal for the hill ecosystem. The pressures on the tectonic plates result several catastrophes in mountain ecology although it provides the minerals and nutrients to the earth surface in some volcanic areas which can be utilized after the millions of years.

Most of the Northern regions of India such as Uttaranchal, Sikkim, Nepal, Bhutan etc are lying on the convergent boundaries of Indian tectonic plate and Eurasian tectonic plate so the regions often experience the earthquakes. The landforms of these regions vary such as hot springs- which pass through the molten chambers of the earth crusts, the wetlands- which develop depressed calderas owing bluish in colour due to the presence of the spectacular natural colour of sulfur colloids etc.

There are numerous wetlands distributed on the convergent boundaries between Indian tectonic plate and Eurasian tectonic plate. Generally, these wetlands are filled up with the ground water, rainwater and glacial melting. The water table of groundwater is significant for maintaining wetland in hilly regions. Hence, the hilly ecosystem is a fragile ecosystem. In regards to bioresources, several studies were undertaken in Sikkim and adjoining Himalaya (Griffith, 1848; Hooker, 1872-1897; King and Pantling, 1898; Biswas and Chopra, 1956; Grierson and Long, 1983; Hara, 1966, 1971).

Thus, the paper is focused on the prominent wetlands of North Eastern part of Sikkim Himalaya along with their unique ancient names as well as the water

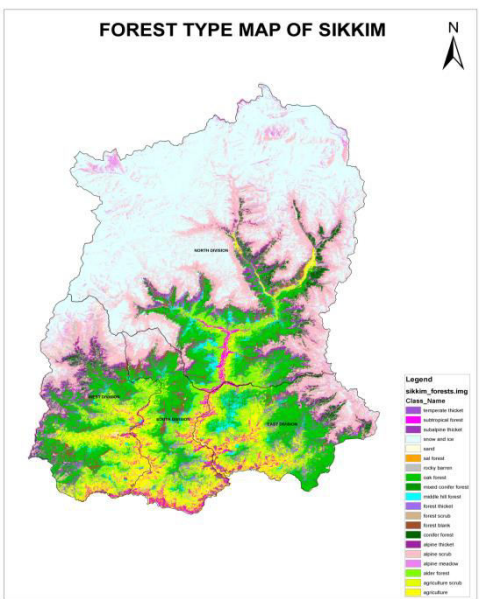
sources of the lower elevation of Tendong, South Sikkim to understand the fragile hills of Sikkim.

I. Sikkim -State

Sikkim is a small mountainous state in the Eastern Himalayan region surrounded by vast stretches of Tibetan plateau, the kingdom of Bhutan and Nepal in North, East and West, respectively. The major strength of Sikkim is that it can display species from tropical to alpine at a glance in a hillock.

Sikkim endowed with rich natural resources and phytogeographically identified as a part of hotspot of Biodiversity under Eastern Himalaya. The alpine Himalayan prairies to tropical hills enrich the Sikkim with majestic beauty. It envoys 0.22 % of the total geographical area of country and eventually has tremendous potential on biodiversity.

Sikkim is strategically significant state for maintaining the mountainous water where the rivers Teesta and Rangit and its tributaries cater the ecological services of Sikkim Himalaya. The river Teesta is the lifeline of Sikkim, West Bengal and Bangladesh. Thus, the role of Teesta and Rangit in the Sikkim Himalaya is significant for the qualitative management of vegetation of Sikkim. As the Sikkim exhibits high ecosystem and species diversity, including outstanding biodiversity assets. It delivers social, economic and environmental benefits for the communities. These assets, in addition to their intrinsic values, deliver clean air and water to the communities as well as provide the natural resources which underpin several strategies for overall development of biodiversity of the Eastern Himalaya. It also justifies the richness of the species diversity in the Sikkim Himalaya. This is an interesting point to put forward that the Sikkim Himalaya, a part of Eastern Himalaya, have biological significant roles for preserving many species.



Source: F&ED, GOS

Fig 1: Sikkim State

II. Potential Wetlands of North Eastern Part of Sikkim

The local names of wetlands of the Sikkim in its North Eastern part are tabulated in the Table 1 as per the survey of India maps, 1965-1968 (Spencer, 1969). It is informative as it contains typical local names of the regions and wetlands.

Table 1: Potential Wetlands of the North Eastern part of Sikkim

Potential Wetland/s Col. I	Pass Col. II	Elevation (ft) Col. III
Gyam-tso-no	Lungma La	19190
	Kangra La	16769
	Tsok La	-
	Gyaogong	-
Yuum-tso	Chumdo	17948
	Bam –tso-la	-
	Say-Say-La	17916
Kha-ring	Khononyangma	19204
Khanchengyao	Gurudongmar	22032
	Byanzay	-
Ranithangpa Tso	Pauhungri	23386
	Karpu La	-
Sangla Phu-Tso	Yume samdung	-
Kasang Tso	Ghera La	-
Chhopup Tso		
Sim Cahokha	Palale	
Chhumzomoi	Phedang Kung	16322
Chameringu		15094

This table is presented to manifest the potential wetlands areas which underpin the significant roles in the biodiversity and ecosystem maintenance. These wetlands provide the mountainous water for mountain ecosystem of alpine region and maintain the pristine biodiversity of high altitude's flora and fauna.

In other word, these are responsible for the maintaining the bioresources (Fig 1, Fig 2). For instance, in the recent past, 1681 MAPs species were enumerated by the Sikkim Government in collaboration with FRLHT, Bangalore (SMPB, 2016). Some of those enlisted species are *Abelmaoschus crinitus* Wall. [Malvaceae], *Abelmaoschus esculentus* (L.) Moench [Malvaceae], *Alelmaoschus manihot* (L.) Medik. [Malvaceae], *Abies densa* W. Griff. ex. Parker [Pinaceae], *Abies spectabilis* (D.Don) Spach [Pinaceae], *Abrus fruticulosus* Wall. ex.Wight & Arn. [Fabaceae], *Abrus precatorius* L. [Fabaceae], *Abutilon indicum* (L.) Sweet [Malvaceae], *Abutilon persicum* (Burm.f) Merr. [Malvaceae], Acacia catechu (L.f.) Willd. [Mimosaceae], *Acacia decurrens* Willd. [Mimosaceae], *Acacia farnesiana* (L.f.) Willd. [Mimosaceae], *Acacia melonoxylon* R.Br. [Mimosaceae], *Acacia pennata* (L.) Willd. [Mimosaceae], *Acacia sinuata* (Lour.) Merr [Mimosaceae], *Acampe papillosa* (Lindl.) Lindl. [Orchidaceae],

Acampe praemorsa (Roxb.) Blatt. & Mccann [Orchidaceae], *Acer acuminatum* Wall. ex. D.Don. [Aceraceae], *Acer cappadocicum* Gleditsch [Aceraceae], *Acer laevigatum* Wall. [Aceraceae], *Acer oblongum* Wall. ex. DC. [Aceraceae], *Achyranthes aspera* L; *Achyranthes bidentata* Blume [Amaranthaceae], *Aconitum bisma* (Ham.) Rapaics. [Ranunculaceae], *Aconitum elwesii* Stapf [Ranunculaceae], *Aconitum falconeri* Stapf [Ranunculaceae], *Aconitum ferox* Wall. ex. Seringe [Ranunculaceae], *Aconitum gammiei* Stapf [Ranunculaceae], *Aconitum hookeri* Stapf [Ranunculaceae], *Acconitum laciniatum* (Bruehl) Stapf [Ranunculaceae], *Aconitum nakaoi* Tamura [Ranunculaceae], *Aconitum naviculare* (Bruehl.) Stapf [Ranunculaceae],*Aesculus assamica* Griff. [Hippocastanaceae], *Aesculus indica* Colebr. ex. Cambess [Hippocastanaceae], *Agave angustifolia* Haw [Agavaceae], *Ageratum conyzoides* L. [Asteraceae], *Ageratum houstonianum* Mill. [Asteraceae], *Aglaia lawii* (Wight.) Saldanha [Meliaceae], Agrimonia pilosa Ledeb. [Rosaceae], Agrostistachys indica Dalz. [Euphorbiaceae], *Ainsliaea aptera* DC. [Asteraceae], *Ainsliaea pteropoda* DC. [Asteraceae], *Ajuga bracteosa* Wall. ex. Benth [Lamiaceae], *Ajuga macrocarpa* Wall ex.. Benth. [Lamiaceae], *Albizia chinensis* (Osbeck) Merr. [Mimosaceae], *Albizia julibrissin* Durass. [Mimosaceae], *Albizia lebbeck* (L.) Benth. [Mimosaceae], *Lindenbergia muraria* (Roxb.) P.Bruche. [Scrophulariaceae], *Lindera neesiana* Benth. [Lauraceae], Lindera pulcherrima Benth. [Lauraceae], Lindernia anagallis (Burm.f.) Pennell [Scrophulariaceae], *Lindernia ruellioides* (Colsm) Pennel. [Scrophulariaceae], *Linum usitatissimum* L. [Linaceae], *Liparis nervosa* (Thunb.) Lindl. [Orchidaceae], *Lippia javanica* (Burm.f.) Spr. [Verbenaceae], *Litchi chinensis* Sonn. [Sapindaceae], *Lithocarpus pachyphyllus* (Kurz) Rehder. [Fagaceae], *Litsea cubeba* (Lour.) Pers. [Lauraceae], *Litsea glutinosa* (Lour.) Robinson [Lauraceae], *Litsea lancifolia* Hook.f. [Lauraceae], *Litsea monopetala* (Roxb.) Pers. [Lauraceae], *Lobaria pulmonaria* (L.) Haffm. [Stictaceae(Lichen)], *Lobelia pyramidalis* Wall. [Lobeliaceae], *Lomatogonium carinthiacum* (Wulf.) Br. [Gentianaceae], *Lonicera macrantha* (D.Don) Spreng. [Caprifoliaceae], *Lonicera spinosa* (Jacquem. ex. Decne) Walp. [Caprifoliaceae], *Lonicera webbiana* Wall. ex. DC. [Caprifoliaceae], *Ludwigia prostrata* Roxb. [Onagraceae], *Luffa acutangula* (L.) Roxb. [Cucurbitaceae], *Luffa graveolens* Roxb. [Cucurbitaceae], *Luisia tenuifolia* Bl. [Orchidaceae Luzula campestris (L.) DC. [Juncaceae], *Lycopodium cernum* L. [Lycopodiaceae], *Lycopodium clavatum* L. --195 [Lycopodiaceae], *Lygodium flexuosum* (L.) Sw. [Lygodiaceae], *Lygodium japonicum* (Thunb.) Sw. [Lygodiaceae], *Lygodium microphyllum* (Cav.) R.Br. [Lygodiaceae], *Lyonia ovalifolia* (Wall.) Drude [Ericaceae], *Macaranga denticulata* (Bl.) Muell.-Arg. [Euphorbiaceae], *Macaranga indica* W. [Euphorbiaceae], *Macaranga peltata* (Roxb.) Muell.-Arg. [Euphorbiaceae], *Machilus villosa* Hk.f. [Lauraceae], *Macrosolen cochinchinensis* (Lour.) Tiegh. [Loranthaceae], *Macrotyloma uniflorum* (Lam.) Ver DC. [Fabaceae], *Maesa chisia* Don. [Myrsinaceae Maesa indica (Roxb.) A.DC. [Myrsinaceae], Maesa montana Dc, [Myrsinaceae], *Maharanga emodi* (Wall.) DC. [Boraginaceae], *Mahonia acanthifolia* Don [Berberidaceae], *Mahonia borealis* Takeda [Berberidaceae], *Mahonia nepaulensis* DC. [Berberidaceae], *Mahonia sikkimensis* Takeda [Berberidaceae], *Malaxis muscifera* (Lindley) Kuntze [Orchidaceae], *Malaxis saprophyta* (King & Prantl) Tang & Wan [Orchidaceae], *Mallotus philippensis* (Lam.) Muell.-Arg. [Euphorbiaceae], *Mallotus repandus* (Willd.) Mull.-Arg.

[Euphorbiaceae], *Mallotus tetracoccus* (Roxb.) Kurz. [Euphorbiaceae], *Malva parviflora* L. [Malvaceae], *Malva verticillata* L. [Malvaceae], *Mangifera indica* L.[Anacardiaceae], *Mangifera sylvatica* Roxb. [Anacardiaceae], *Manihot esculenta* Crantz [Euphorbiaceae], *Marsdenia roylei* Wight [Asclepiadaceae], *Marsdenia tinctoria* R. Br. [Asclepiadaceae], *Mazus pumilus* (Burm.f.) Van Steenis [Scrophulariaceae], *Meconopsis aculeata* Royle [Papaveraceae], *Meconopsis nepaulensis* DC. [Papaveraceae], *Meconopsis paniculata* (D.Don) Prain. [Papaveraceae], *Meconopsis simplicifolia* (G.Don)Walp. [Papaveraceae], *Melia azedarach* L. [Meliaceae] to name a few.

In addition to this, the newly updated medicinal plants of Sikkim Himalaya are namely, *Allium prattii* C. H. Wright ex Hemsley [Liliaceae], *Anaphalis xylorhiza* Schultz [Asteraceae], *Anisodus luridus* Link [Solanaceae], *Arenaria densissima* Wallich ex Edgeworth & J. D. Hooker [Family: Caryophyllaceae], *Aster souliei* Franchet [Asteraceae], *Bistorta macrophylla* (D.Don) Soják [Polygonaceae], *Carex atrofusca* Schkuhr subsp. *minor* (Boott) T. Koyama [Cyperaceae], *Carex gracilenta* Boott ex Boeckeler [Cyperaceae], *Codonopsis foetens* J. D. Hooker & Thomson[Campanulaceae], *Dontostemon glandulosus* (Karelin & Kirilov) O. E. Schulz [Brassicaceae], *Gentiana tibetica* King ex J. D. Hooker[Gentianaceae], *Halerpestes sarmentosa* (Adams) Komarov & Alissova [Ranunculaceae], *Hypecoum leptocarpum* J. D. Hooker & Thomson, [Papaveraceae], *Juncus leucanthus* Royle ex D. Don [Juncaceae], *Kobresia pygmaea* (C. B. Clarke) C. B. Clarke [Cyperaceae], *Kobresia schoenoides* (C.A.Meyer)Steudel[Cyperaceae], *Leontopodium monocephalum* Edgeworth [Asteraceae], *Meconopsis horridula* J. D. Hooker & Thomson [Papaveraceae], *Notopterygium forbesii* H.Boiss [Apiaceae], *Onosma hookeri* C. B. Clarke [Boraginaceae], *Pedicularis longiflora* Rudolph [Scrophulariaceae], *Pedicularis oliveriana* Prain [Scrophulariaceae], *Polygonatum cirrhifolium* (Wall.) Royle [Liliaceae], *Potentilla arbuscula* D. Don [Rosaceae], *Pterocephalus hookeri* (C. B. Clarke) E. Pritzel [Dipsacaceae], *Ranunculus hirtellus* Royle [Ranunculaceae], *Rhododendron cephalanthum* Franchet, [Apiaceae] *Rhododendron fulgens* J. D. Hooker [Apiaceae] *Salix sikkimensis* Andersosson, *Sambucus adnata* Wallich ex Candolle [Caprifoliaceae], *Soroseris hookeriana* Stebbins [Asteraceae], *Tanacetum nubigenum* Wallich [Asteraceae], *Taraxacum* sect. *Tibetana* Soest, [Asteraceae] and *Trisetum spicatum* (Linnaeus) K. Richter[Poaceae] (Pradhan and Maity, 2021).

III. Ecological challenges

At the lower elevation of the Sikkim, the water resources are facing ecological challenges. The fragile ecosystem of Sikkim is experiencing the drying water sources, hot springs and lakes. For instance, dried hotspring of Tholung, Nagi Lake of South Sikkim etc. Likewise, the few water sources in the Tendong Reserve Forests depicted the water shortage (Table 2) as per the survey (Pradhan, 2017). Such water scarcity impacts on the vegetation matrix of the region which in turn, may affect socio-economic aspects of the region (Fig. 2). Such deficit of water potential (Ψ) leads to the accumulation of the phenolic compounds, proline, antioxidant enzymes (Boughalleb and Mhamdi, 2011;

Jiroutova, *et al.*, 2021). As the consequence of water deficit in the region, the vegetation matrix of Sikkim and Himalayan region has been affected where the plant relocation is occuring from lower elevation to the higher elevation in the mountain ecology.

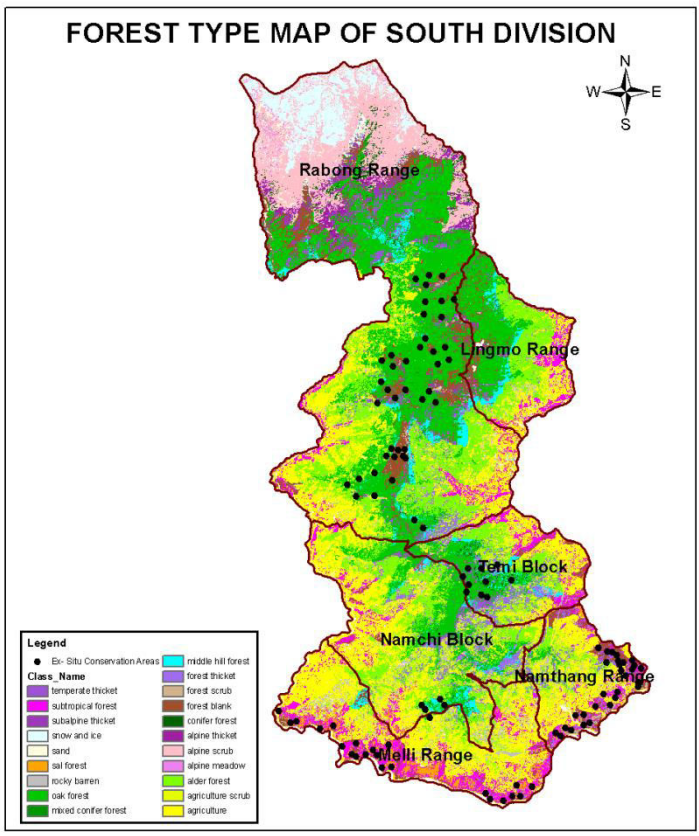
Table 2: Water Sources of Tendong Reserve Forests of South District, Sikkim

Sl No	Geographical Positioning System	Place Name/s	Elevation (m)
1	N 27°12' 13.4" E 088°24' 46.8"	Dong	2330 m
2	N 27°12' 05.3" E 088°24' 31.5"	Kai-la Kharka	2113 m
3	N 27°11' 46.9" E 088°24' 12.8"	Birkuna	2138 m
4	N 27°13' 53.3" E 088° 24' 07.9"	Dewall Pani	2110 m
5	N 27°13' 47.8" E 088°23' 18.5"	Kuwa pani	2035 m
6	N 27°14' 02.6" E 088°24' 23.4"	Lamay Tar	1947 m
7	N 27 12 38.2 E 088 25 36.0	Kazi tar	2010 m
8	N 27° 12' 33.5" E 088° 25' 00.1"	Kazikharka Pokhari	2255 m
9	N 27° 13' 53.9" E 088° 24' 18.1"	Dharey, Lamey Tar	2071 m
10	N 27° 13' 83.9" E 088° 24' 05.4"	Deu Forest	2044 m
11	N 27° 14' 00.2" E 088° 24' 28.1"	Lamey Tar	1954 m
12	N 27° 12' 06.2" E 088° 25' 25.6"	Bakhimpanidevithan	1912 m
13	N 27° 13' 44.8" E 088° 26' 46.8"	Pabongkhola	1477 m
14	N 27° 13' 21.6" E 088° 25' 34.6"	Pabong Stream	1500 m
15	N 27° 12' 18.1" E 088° 24' 59.0"	Khop	2308 m

This depicts that the vegetation of the region is essential for the maintenance of the ecosystem for recharging the groundwater for the wetland, water sources etc. Across the globe, the water table is decreasing that has been cascading effect on the flora and fauna. The low water potential in the plants affects the physiological process causing water-stress to the plant. And it also affects the tree canopy leading to the aridness in the regions.

Thus, the tree canopy is paramount for the recharging of the groundwater in both hills and plains. Several contrivances for the recharging of groundwater must be adopted such as drainage, afforestation, natural regeneration etc. Eventually, it is also essential to maintain the SIAL and SEMA of the earth crust where no disruption in the Upper Mantle and Crust must be ensured for sustainable water sources else it causes aridness in the region.

Therefore, the fragile mountain ecology of Sikkim must devise with comprehensive plan to go along with the development. However, it warrants further researches on the wetlands of Sikkim, glacier recession and thermal expansion to understand the fradile mountain ecology of Sikkim.



Source: F&ED, GOS.

Fig 2: Forest Type of South District

Acknowledgements

Authors are thankful to the Forest and Environment Department, Government of Sikkim for the research support, Working Plan(F& ED) and the staffs of QCL-HARC, Forest and Environment Department.

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