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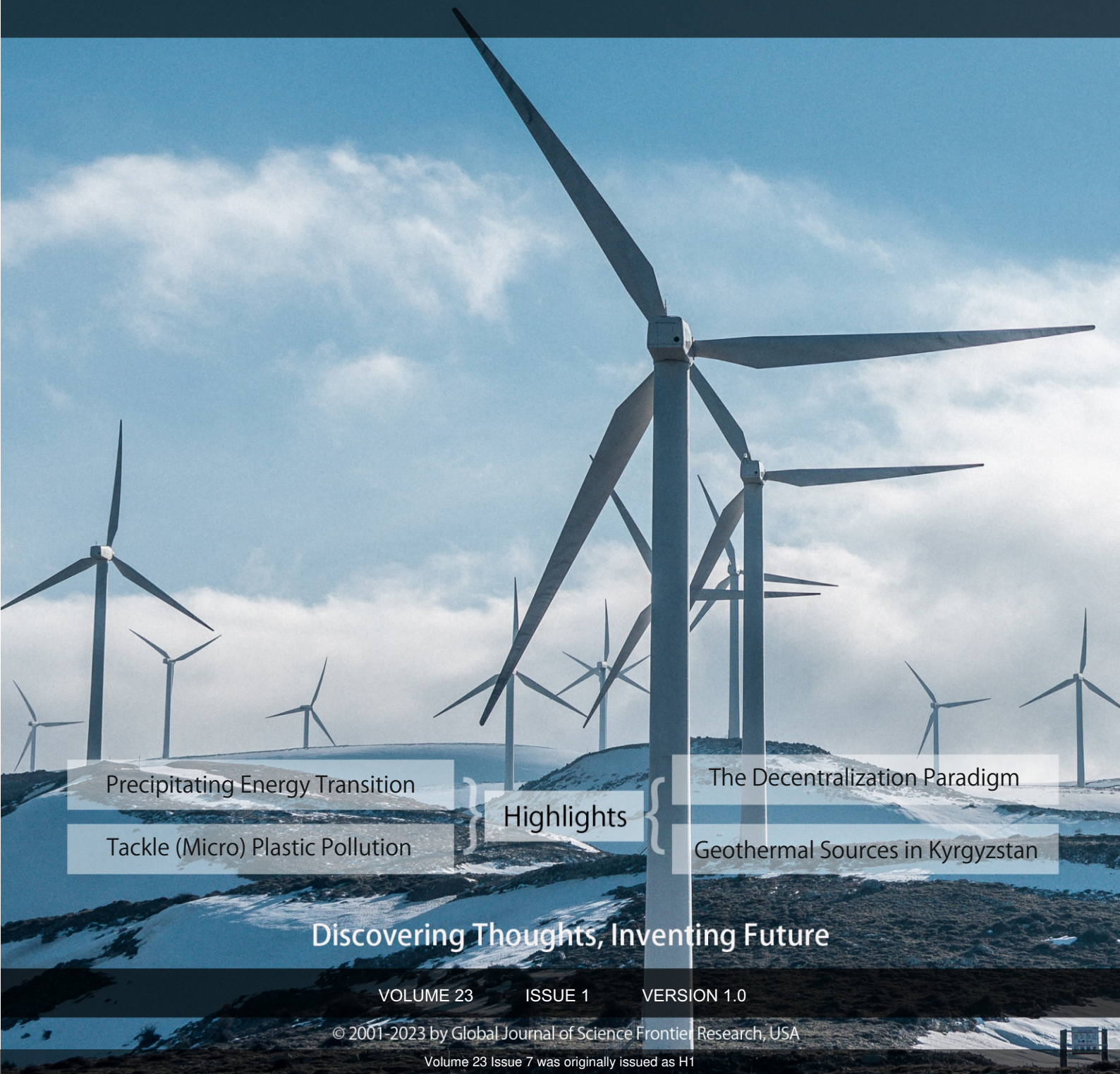

Precipitating Energy Transition

Tackle (Micro) Plastic Pollution

Highlights

The Decentralization Paradigm

Geothermal Sources in Kyrgyzstan

Discovering Thoughts, Inventing Future

VOLUME 23 ISSUE 1 VERSION 1.0

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# Aligning Interests or Precipitating Energy Transition

By Miguel Schloss

*Abstract-* *"History does not repeat but it does rhyme"*

Tyler Cowen

A lot has been debated about the effects of carbon emissions and their impact climate change. Of all the issues that need to be addressed, the one that stands out refers to the power sector, which absorbs more primary energy than any other sector, and accounts for anywhere between a third and half of carbon emissions worldwide.

At stake is the need to assure continued economic development, and assuring the associated improvements in standards of living. Over the decades, growth has been propelled by massive expansion of energy demand, powered by hydrocarbons that brought about increases in CO2 emissions.

In recent years, an increasing consensus has emerged that there is a need to reverse these emissions to prevent global average atmospheric from generating further temperature increases. To this end, 195 countries entered into an international agreement in Paris to limit temperature increase 1.5 degrees Centigrade of pre-industrial levels by mid-century – but there is still a long way to go to cap global warming at this level, and thus no basis for complacence.

*Keywords:* *paris agreement, climate change, decarbonization, fossil fuels, renewables, regulatory controls, enabling conditions.*

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# Aligning Interests or Precipitating Energy Transition

Miguel Schloss

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In recent years, an increasing consensus has emerged that there is a need to reverse these emissions to prevent global average atmospheric from generating further temperature increases. To this end, 195 countries entered into an international agreement in Paris to limit temperature increase 1.5 degrees Centigrade of pre-industrial levels by mid-century – but there is still a long way to go to cap global warming at this level, and thus no basis for complacence.

Actually, progress towards this aim remained negligible over the last 20 years, with marginal changes in CO2 emissions. This paper does not address the wide range of issues, such as what to do on research and development of new technologies, hard-to-abate sectors like mining, shipping, etc. Instead, it focuses on a simmering (and at times ideological) debate on how to respond to this lack of progress – i.e., by instituting stronger environment regulations and associated monitoring to force enterprises to set up plans and investments aimed at reducing emissions, or enhancing enabling conditions for investment environment through pricing and taxation policies to facilitate financial and human resource mobilization to deal with the issue.

This article is focused on this apparent dilemma to enhance progress and results in climate change actions. As there are few precedents in this emerging area, this article is based on benchmark analysis the author has conducted to assist several Governments in designing policies to deal with the emerging issues that climate change is posing.

*Keywords:* *paris agreement, climate change, decarbonization, fossil fuels, renewables, regulatory controls, enabling conditions.*

## I. Introduction: Current Issues

*"Eternity is a very long time, particularly towards the end",*

Woody Allen

The Paris Agreement on climate change aims at limiting global warming to no more than 1.5°C of pre-industrial levels and a decarbonized economy by mid-century[1].

This implies investments of at least US$16.5 trillion, and a profound transformation in production and transportation practices, investments in renewable energy, and other actions never seen to date.

No political, social or moral achievement of this magnitude or complexity is without formidable obstacles. There are vested interests to be confronted, attitudes to be changed, resistances to be overcome. The problems are immediate, the ultimate goal frustratingly far away.

The crisis triggered in Europe by the suspension of Russian gas supply, together with decisions to curb production of hydrocarbons, illustrate the disconnect of the actions taken with geopolitical realities. These have triggered price increases to record levels, and a gap between the goals and achievements of the Paris agreements. A transition towards the agreed objectives will demand a decidedly more strategic and coherent approach[2].

This will require special attention to coal-dependent economies such as India and South Africa – which generate more than 70 and 85% of their electricity, respectively, from low cost coal, with serious social and economic repercussions that will need more nuanced approaches to transition than those applied to date.

Likewise, focused efforts will be required in countries with important generation facilities or in energy-intensive and harder-to-abate sectors that are difficult to decarbonize, such as mining and extractive industries.

Any effort of this nature will require important human and financial resources to make progress within

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[1] United Nations Framework Convention on Climate Change (FCC – Conference of the Parties – Paris, France (Dec. 2015). https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris- agreement.

[2] Mapping Carbon Neutrality in Uncharted Territory, Miguel Schloss; Generis Publishing, 2022. https://www.generis-publishing.com/book.php? title=mapping-carbon-neutrality-in-uncharted- territory-521.



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the absorption capacity of each country. Forcing ambitious and distant goals, or discouraging certain technologies with arbitrary regulations will not generate progress. A more promising path is to align interests through pricing and taxation practices that adequately reflect environmental costs, and facilitate investments responsive to consumers, avoiding complicated coordination.

## II. The Emerging Reality

"Quis custodiet ipsos custodes?" (Who watches the watchers?) Latin locution by Juvenal.

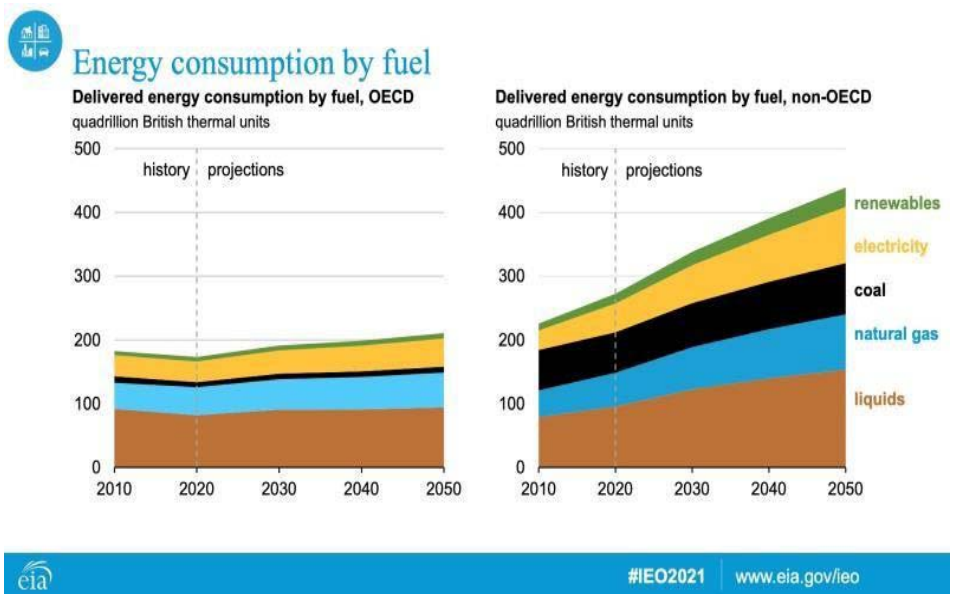
The lack of foresight, the low energy security implied by the energy matrix and the consequent crisis triggered by the conflict in Ukraine have prompted the 51 largest economies to double support for fossil fuels to almost US$700 billion in 2021, and even larger amounts in 2022 - there by mitigating energy price increases for consumers, while generating incentives for increased fossil fuels supply to achieve a quick response to overcome the energy crisis. This is undermining the elimination of inefficient and distorting subsidies, flagrantly contradicting the declared ecology friendly policies and pledges[3].

This practice was not only limited to major economies where fossil fuels consumption is the greatest, but spread to emerging countries, such as Chile, which had instituted countercyclical practices of subsidies (when prices increased) and taxes when fossil fuel prices declined, in such a way that on average, there was no subsidy. This provided for a proper level-playing field for renewables, and enabled major investments in renewables (see Attachment). However, with current global subsidy practices, the fiscal cost associated with financing fuels of almost US$3 billion was written off, involving a reduction equivalent to 74,000 social housing or 3.7 times the annual subsidy to the Trans-Santiago public transport system, which illustrates the social cost of such action.

More broadly, regulatory interventions have generated counter- productive results through institutions with crossed, and often conflicting responsibilities, where technical factors and political factors are mixed. Oftentimes, this has generated disincentives of costly delays, resulting in projects taking longer to process for approval than to execute.

Clearly, environmental institutions are generating costly inefficiencies, undue room for discretion and arbitrariness, and associated risks of corruption. A central objective of institutional redesign should reduce these spaces and offer higher levels of certainty and objectivity, and economic grounded criteria, to generate energy supply that is affordable, reliable and cleaner. In this way, environmental decisions would be more integrated to economic development imperatives and market demands[4].

Moreover, as early phases of development tend to be more energy intensive as new machinery needs are introduced, the growing energy demands that will take place mainly in emerging economies (as can be seen in the graph below)[5].

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[5] Global Journal of Management and Business Research, 2022; Miguel Schloss—Changing the Conversation on energy Transition. https://drive.google.com/file/d/13diV_LtnNa0iq_3KBZvbR6afW7L_Le/view.

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This will facilitate the introduction of more advanced technologies in new plants, which are less cumbersome than conversion or decomissioning of existing ones, improving the impact on the global energy matrix.

However, the obsession with restricting hydrocarbons and consequent insufficient investment in conventional energy (to overcome limitations of renewable energies that depend on climatic factors requiring support from traditional sources), has damaged energy security and a transition that responds to the greater demand[6].

Decarbonizing the energy sector and simultaneously meeting rapidly expanding energy demand is perhaps the most important challenge facing global development. As new technologies develop and become more competitive, a greater share of increased power demand will be supplied by renewables, together with proper backups from traditional energy sources, thereby providing a more resilient and balanced energy matrix:

## III. Conclusion: the Way Forward

"If we don't change our direction, we're likely to end up where we're headed" Chinese proverb.

So much of the climate change debate is deeply emotional and inflammatory, rather than open-minded and probing. The point of this paper isn't to take sides in what often are quite often are complex disputes. The lack of progress should in itself be a warning that we are on a trajectory that is far from decisively correct.

Looking towards the future, all indications are that in the 21st century the world will face twin energy-related threats: that of not having adequate and secure energy supplies at affordable prices and that of environmental harm caused by consuming too much energy in inappropriate ways.

Responding to either of these threats could be relatively straightforward; however, a solution to both simultaneously is one of the great challenges facing this century, and will require particular attention to the following:

*First:* With global energy demand increases, calling for a cut in consumption is not a viable option, as it would undermine much needed economic development, particularly in emerging economies. Inevitably, fossil fuels have an important role to play as back-ups of renewables, to cover for shortfalls resulting from their reliance on natural conditions (e.g., solar during evenings or poor weather conditions, or eolian when wind conditions are insufficient).

*Second:* The path cannot be limited to renewable energies per se, but the reduction of carbon emissions with a variety of technologies, the widespread deployment of carbon capture, use and storage, and the alignment of interests through pricing and taxation policies that facilitate the mobilization resources to investments required by the transition[7].

*Third:* An integrated approach will be inevitable, as investments must respond to environmental goals, as much as affordability and reliability, under volatile supply, demand and financial markets conditions. This will require a balanced approach that responds to tradeoffs among sources of energy supply, and ensures a flexible supply chain response with resilient cost efficiency.

*Fourth:* This, requires, however, defraying the incremental costs of tackling climate change in the order of 1-2 % of GDP, which makes the entire issue politically charged, particularly which countries and segments of the population need to defray such costs, and how the inevitable risks are going to be managed. As both the scale and manner of mobilizing resources have failed to respond in a manner to generate tangible progress, the time has come to reset the role that multilaterals (particularly the World Bank and the IMF), to ensure that resources are mobilized in magnitudes and with proper policy frameworks to fund incremental investments and ensure their long- term sustainability.

All said, the critical question is not to try and pick which technology or top-down approach, which all too often have proven to be ineffective. Given the uncertainties, technological developments that still need to take place, and an unstable and unpredictable future, the outcomes will hinge on how we put in place systems to ensure that the creativity of the market develops and allocates resources to those technologies and approaches that move the energy mix in the right direction at the lowest cost.

Any regulatory process should be as supportive as possible, and be within the institutional capacities of the country concerned. In doing so, every effort should be made to generate incentives towards managing sustainability, rather than mere compliance, or even worse "greenwashing", gaming the system, and consequent missed opportunities for innovation, efficiencies, and social benefits.

[6] Investment in traditional energy for transition, HE Suhail Mohamed Al Mzrouei, The Banker, Oct. 22,2022 https://www.thebanker.Com/content/search/(offset)/180?SearchText=October+2022&sortBy=published&SearchType=articles.

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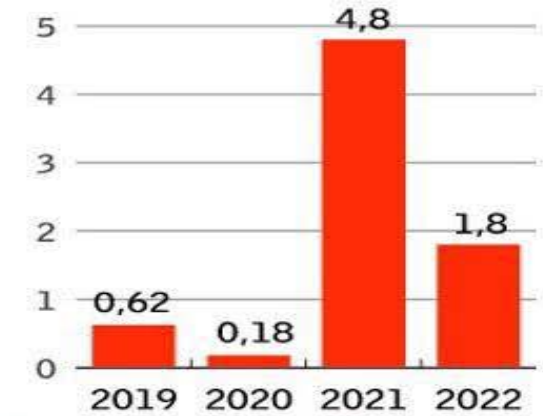
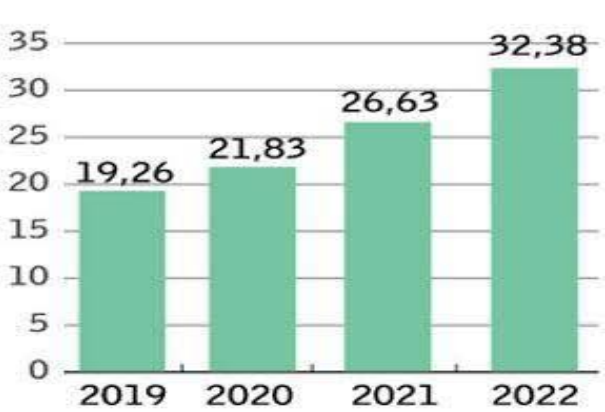
*Annex*

Outcome of Energy Transition Policies in Chile




**Generación por fuente total** (en TWh)

| | 2022 | 2021 | Var. % |
|---|---|---|---|
| Eólica | 8,8 | 7,2 | 22,4 |
| Geotérmica | 0,5 | 0,3 | 43,8 |
| Hidráulica | 20,1 | 16,3 | 23,2 |
| Solar | 14,1 | 10,5 | 33,4 |
| Térmica | 38,9 | 46,5 | -16,3 |

**Generación renovable no convencional** (en TWh)

| | 2022 | 2021 | Var. % |
|---|---|---|---|
| Biomasa | 1,51 | 1,63 | -7,4 |
| Eólica | 8,75 | 7,15 | 22,4 |
| Pasada (minihidro) | 2,23 | 2,05 | 8,8 |
| Solar | 14,03 | 10,53 | 33,2 |

**Generación térmica** (en TWh)

| | 2022 | 2021 | Var. % |
|---|---|---|---|
| Biomasa | 1,65 | 1,86 | -11,3 |
| Carbón | 19,03 | 27,47 | -30,7 |
| Diésel | 1,48 | 1,81 | -18,2 |
| Gas Natural | 15,84 | 14,48 | 9,4 |

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# The Decentralization Paradigm: Pathway for Communities' Rights to Land in Cameroon

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*Keywords: communities' lands, decentralization, communities' rights, land ownership and land management.*

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# The Decentralization Paradigm: Pathway for Communities' Rights to Land in Cameroon

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*Abstract-* The devolution of power and resources by the State to local authorities much en vogue today in Cameroon and other areas of the world is fast becoming a governance model which could be relied upon for the assertion and articulation of communities based land management and ownership rights. This is so given that the advantages of bringing local communities to the decision-making centres to determine the fate of local lands and resource ownership and control can hardly be exhaustive in any single legal debate. Besides, it might be key to determining communities' rights, while enhancing the dignity of its members. After all, communities' lands are not only owned by a single generation, but by those considered as ancestors, the living and those yet to be born. To this effect, an attempt to weave the pieces of national land legislations within the decentralization paradigm arguably remains ideal in articulating efficient land governance. Thus, if Cameroonian government is embracing decentralization as governance option, then she must beside other things be ready and prepared to relinquish her high-handed and overwhelming powers and control over land and land resources to local stake holders especially local collectivities which could be construed to reflect the aspirations of the local communities they are supposed to represent.

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## I. Introduction

Land[1] plays significant roles to nature and humans alike. While it harnesses the ability to host varied Earth's ecosystems, it offers different opportunities for human livelihoods, cultural heritage, development, identity, well-being and dignity - characteristics of modern society. Because of the benefits humans enjoy from land, they have and are imperatively becoming *stewards* over land and over land resources, most especially those in the local communities generally considered *untitled*, yet collectively owned.[2] It is from this prism most importantly, that humans have through different international legal platforms engaged to respect and secure nature including land and its essential processes especially in the planning and implementation of their social and economic developmental activities.[3] But how will this not be so, when development especially in developing countries usually entails the forceful eviction or displacement of peoples especially those at the local communities to make way for large-scale business projects such as dams, mines, oil and gas installations or ports. In many countries, Cameroon inclusive, a considerable portion of this displacements are carried out in manners deemed to be inconsistent with basic human rights of host communities,[4] thus, further aggravating their already precarious land rights curtailment especially through State's complaisance.[5]

From the above, the word land might be hardly understood from a single-shot definition. While English Law might have given a wide and broad view of what constitute land, it circumferences ownership over the same to include land of any tenure, mines and minerals whether or not the division is horizontal, vertical or other way.[6] In this regard, rights over land could be perceived through the doctrines *of superficies solo cedit*–whatever is attached to land forms part of it, or *quicquid plantatur solo, solo cedit* – whatever is affixed to the soil belongs to the soil.[7] The access therefore, use of, and control

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[1] In Black's Law Dictionary, (1968), 4th Edition, pp. 1020-1022, 'Land' has been considered to go beyond the soil or earth. It include things of a permanent nature affixed thereto or found therein, whether by nature, as water, trees, grass, herbage, other natural or perennial products growing crops or trees, mineral under the surface or by hand of man, as buildings, fixtures, fences, bridges, as well as works constructed for use. From this explanation, land include the soil and things found on its surface as well as those found below the surface, where occurring naturally or otherwise.

[2] Rosset, P. et al. (2006), Promises Land: Competing Visions of Agrarian Reform. Institute for Food and Development Policy. Food First, Oakland, CA, USA; Borras, S. (2007), Pro-Poor Land Reform: A Critique. The University of Ottawa, ON, USA.

[3] According to Principle 10(b), World Charter for Nature, (1982), *"…the productivity of the soils shall be maintained or enhanced through measures which safeguard their long-term fertility and the process of organic decomposition, and prevent erosion and all other forms of degradation…"*

[4] In 2009 for instance, the Cameroonian Minister of Economy signed a convention with SG Sustainable Oils Cameroon (SGSOC), a subsidiary of the US-owned Heracles Farms to occupy 180, 599 acres of land in the South West Region of Cameroon with palm oil plantation. This was done at the behest of over 14.000 peoples who inhabited the area, and without their consent. This however led to a stiff resistance from the local peoples.

[5] Article 1(2), Ordinance No. 74-1 of 6th July 1974 to Establish Rules Governing Land Tenure is to the effect that, "…State shall be the guardian of all lands…"

[6] See Section 205(1), (ix), English Property Act, (1925).

[7] Following article 9 of the British Mandate to on behalf of the League of Nations administer Southern Cameroons, she was accorded full



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over land directly affect the enjoyment of a wide range of human rights. Arguably, it is the human rights dimension of land management that enhances the link between land and development, peace and disaster prevention.

In Cameroon, rights over land are a reflection of different tenure systems as was the orientation before, during and after colonialism. Under customary law for instance, the ownership of land would not necessarily include the ownership of fixtures. Thus, ownership of crops might not signify ownership of land.[8] It is this disparity in customary ownership and rights over land that might had inspired the Yoruba King, *Gboteyei* to consider land to be owned by a kind of *vast family* in which many are dead, with few living and countless yet to be born.[9] This position was and is still being exploited by colonial powers, post and neo-colonial governments at the detriment of such local communities when it comes to land use and management especially for large investment and infrastructural projects. However, while the claim over land ownership in Cameroon appears to be problematic, the greater issue further lies on the exercise of usufruct rights over the little areas that have been textually apportioned to other interests apart from that of the State. No doubt, this worry seems to be further laddened by the legislative disposition to the effect that, it is the State which retains overwhelming powers over land as sole guarantor and determinant of the types and forms of rights other stakeholders should exercise over land.[10]

However, the stark and delicate nature of the above situation seems to be a reminder to the State of the dormy and highhanded nature with which land issues seemed to have been handled ever since the adoption of the 1974 land laws in Cameroon. The time seems to have come when the central authority needs to relinquish some of the overwhelming powers exerted over land management to other entities especially at the local level. Time seem to have come when the narratives given to national lands, that is lands over which local communities exercise rights needs to be revisited. The time when local communities should no longer be made *squatters* over their own lands or *mere spectators* over the management of their own lands seems to have come.

With the adoption of the decentralization paradigm in Cameroon,[11] there is much hope that local communities shall hence become part and parcel of the land expropriation committee for instance, which as of date excludes them only to be comprised of the Prefect of the Division concerned as secretary, Divisional Representatives of Lands Department as members; a Surveyor from the Surveys Department, and Technical Expert in construction, and Technical Expert from Ministry of Agriculture.[12] While this is so, local populations become *mere spectators* in the sense that, they are merely invited to participate without any defined duties or role to play. Thus,

> *The populations concerned who shall be informed no less than fifteen days in advance by the Prefect of the expropriation must be invited to participate in all the stages of the investigation.*[13]

Decentralization which is the devolution by the State of special powers and appropriate resources to local authorities remains the hopeful driving force for the promotion of development, democracy and good governance especially concerning land interests at the local level. In this regard, for the State to implement a project on the 'territory' of a Council, the opinions of the Council concerned needs to be sought. This is so given that national lands can be registered in the name of Councils for the implementation of projects for the interest of the people. Thus,

> *"grassroots civil society associations and organizations as well as neighbourhood and village committees shall contribute to achieving the objectives of local authorities."*[14]However, while the nature of such contribution remains undetermined, it

power to administer Southern Cameroons and adopt legislations there upon in accordance with her laws and as integral part of her territory. While this applies same to French Cameroon, there was the exportation of the English Common Law and French civil law to Cameroon. The quantum of English applicable laws in the Southern Cameroons was sanctioned by section 11 of the Southern Cameroons High Court Law (SCHCL), of 1955, which provided for the application of English Common Law, the doctrines of equity and statutes of general application, which were in force in England on January 1st 1900. By virtue of this, British and Nigerian laws were applicable in the former Southern Cameroons including traditional customary practices, given that the latter was not repugnant to natural justice and good conscience.

[8] This has been variously illustrated in court decisions including: *Enjema Liote V. Hanna Forty, (1984), CASWP/CC/15/83, (unreported) and Mallam Bello V. The People, (1983), Suit No. BCA/9MS/83, (unreported)* among many others. Also see Bongba, E. and Tanto, R. (2019), Land Disputes and Family Ties in Cameroon: Debating the Possibilities of Reconciliation. In: Green MC (ed.), Law, Religion and Human Flourishing in Africa. Stallenbosch, African Sun Media.

[9] See Kaspa, N. (2019), Gender, Decision-Making on Land Ownership and Indigenous Rights in Cameroon: Searching for a Balance in Law. International Journal of Science and Research, (IJSR), volume 9, issue, 12. ISSN: 2319-7064, p. 683. Cited from: Namnso, B. et al. (2014), *Land Ownership in Nigeria: Historical Development, Current Issues and Future Expectations*. Journal of Environment and Earth Science. Volume 4, no. 21, pp. 182-188.

[10] See articles 1(1) and (2); 12; 13 and 18 Ordinance No. 74-1 of 6th July, 1974, to Establish Rules Governing Land Tenure. Also see article 4(1); (2) and (3) of Ordinance No. 74-3 of 6th July 1974 Concerning the Procedure Governing Expropriation for Public Purpose and the Terms and Conditions of Compensation.

[11] Law No. 2019/024 of 24 December, 2019 to Institute Bill on the General Code of Regional and Local Authorities.

[12] Article 4(2), of Ordinance No. 74-3 of 6th July 1974 Concerning the Procedure Governing Expropriation for Public Purpose and the Terms and Conditions of Compensation.

[13] Article 5 ibid.

[14] See section 41, Law No. 2019/024 of 24 December, 2019 to Institute Bill on the General Code of Regional and Local Authorities.

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gives glimpse of hope since the law aspires for the inclusion of local communities in the helm and management of their own affairs especially concerning land.

## II. Determining Rights Enjoyed by Local Communities Over Land

To enhance the enjoyment of rights over land in Cameroon, land has been classified into three broad categories.[15] From here it is understood that, local communities have their rights inserted upon national lands given that, these are portions of land that have not been titled neither under State ownership nor under private domain. As such they remain at the disposition of local communities which can exercise right either by way of construction of houses or by practicing cultivation of crops, plantations, grazing or in any other manner that can proof human presence and development.[16] While this is so, it is regrettable that local communities' rights might be sapped away over lands considered to be *free* of any effective occupation. These lands are administered not by its occupants but by the State which can grant such parcels through lease or assignment to other users, mostly without or limited consultation of concerned communities. But then, which are the various rights that communities enjoy on lands under their control?

### a) The Right of Occupancy

Before State-control over land became a model, local communities' rights over land were asserted through their ability to collectively capture and defend parcels of lands against outsiders. These rights were enjoyed through inherited group membership.[17] With the introduction of the French and British Administrations, such occupiers in Cameroon were to transform such occupancy through the obtention of *livrets fonciers* and *certificates of occupancy* respectively.[18] Nevertheless, under the land legislations, communities' occupancy could only be effective, if members of such communities can show proof of buildings, farms, plantations, grazing, and the manifestation of other aspects of human presence.[19]

However, the view that local communities are mere occupiers of the lands they inhabit and have inhabited from time immemorial may just be a way of depriving them of their ownership right. Thus, they might occupy with buildings but permanent rights over sub-soil belong to the State through the public property regime.[20] It is not therefore for fancy that occupancy is likened to *use* only.

### b) Hunting and Fruit Picking Right

Hunting and fruit picking has been recognized as a *granted right* to local communities over lands considered being *free* of any effective occupation.[21] This right has been given further recognition in the 1994 Forestry Law. In this regard, customary right has been taken to mean the 'right which is recognized as being that of the local population to harvest all forest, wildlife and fisheries products freely for their personal use.'[22] While the recognition of this right by the State is significant for local communities, it should be underscored that local communities' needs goes far beyond mere hunting[23] and picking.[24]

Local communities share a common attachment not only to their land but also to their forests of which they often have thorough knowledge and which they most importantly consider to be common property to be accessed and used without restriction.[25] They consider their land as the foundation of their existence. Its incarnation to them is their *foster mother*, the very source of their food and pharmacopoeia and the setting for their cultural and spiritual recreation and celebration. While this is so, the State has considered among the domain of public lands, communities' marsh lands, lakes, ponds, lagoons, and even non-navigable water ways,[26] and the question lingers on if by such inclusion within public lands the State is not in a way depriving local communities of their rights over these properties found on their lands or further a confirmation to the

[15] The different categories include: State lands, private lands and national lands.
[16] Article 15(1), Ordinance No. 74-1 of July 6th, 1974 to Establish Rules Governing Land Tenure.
[17] Alden, W. (2018), Collective Land Ownership in the 21st Century: Overview of Global Trends. *Land,*vol. 7, Iss. 68. Van Vollenhoven Institute, Leiden Law School, P.O. Box 9520, 2300 RA Leiden, The Netherlands. Pp. 1-26. Also available at: http://www.mdpi.com /journal/land (consulted on the 15th of August, 2022).
[18] Anne-Gaelle, J. (2013), Land registration in Cameroon. In: *Focus on Land in Africa: Placing Land Rights at the Heart of Development.* Brief – Cameroon. Pp. 1-7.
[19] Article 15(1), Ordinance No. 74-1 of July 6th, 1974 to Establish Rules Governing Land Tenure, op cit.
[20] Article 3(1), Ordinance No. 74-2 of 6th July 1974 to Establish Rules Governing State Lands.
[21] Egbe, S. (1997), Forest Tenure and Access to Forest Resources in Cameroon. Forest Participation Series No.6.International Institute for Environment and Development (IIED), London. Available at: http://www.iied.org/pubs/pdfs/7521IIED.pdf (accessed 19 September 2022).
[22] Section 8(1), Law No. 94/01 of 20th January, 1994 to Lay Down Forestry, Wildlife and Fisheries Regulations.
[23] Traditional hunting exercised by local communities is authorized by law in Cameroon. See to this effect, Section 86(1), ibid.
[24] Bongba, E. and Tanto, R. (2019), Land Disputes and Family Ties in Cameroon: Debating the Possibilities of Reconciliation. In: Green, MC. (ed). *Law, Religion, and Human Flourishing in Africa*. Stellenbosch Conference-RAP. Pp. 277-293.
[25] Nguiffo, S. et al. (2009), The Influence of Historical and Contemporary Land Laws on Indigenous Peoples' Land Rights in Cameroon. In*: Land Rights and the Forest Peoples of Africa: Historical, Legal and Anthropological Perspectives.* Forest Peoples Programmes, Stratford Road, United Kingdom. Pp. 1-24.
[26] Article 3, Ordinance No. 74-2 of July 6, 1974, To Establish Rules Governing State Lands.



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opinion that local communities are mere squatters on their own lands.

*c) Ownership Right or Titling*

Since 1974, the Cameroonian legislator has conditioned land ownership to the acquisition of land certificates.[27] In this regard, local communities as well as members thereof may apply for land certificates for their parcel.[28] Without such certificate, it is considered that they are mere occupants or simply users of such lands for the time being as such lands can be subject to lease or assigned to other users as the State deems necessary. This may especially be considered so given that, land resources such as forests and forest products owned by local communities are considered to be found on national lands which according to the Forestry Law constitute non-permanent or unclassified forests.[29]

With ownership or titling right, local communities can actually play key role in the lease of their own lands.[30] To this effect, they enjoy the right of preemption in the event of alienation of products found in their forests for instance.[31]

*d) Consultative and Compensatory Rights*

National land over which local communities' rights can be exercised, their effective utilization and administration is guaranteed by the State.[32] With such powers the State can therefore give her consent for the expropriation of such lands for instance especially for public purposes. In this regard, local communities inhabiting such lands *may* be consulted. Consultation may be carried out at different levels and for different reasons.[33] While the Land Consultative Board ensures on behalf of the State proper administration of national lands, community leaders are generally members of the board.[34] Such leaders or traditional authorities may include: village chiefs and two leading members of the village or community where the land is situated.[35] Also, the population where lands need to be expropriated (local population) might be invited, not only to be consulted but also to participate in the stages of investigation of portion of lands earmarked for expropriation.[36] However, it is regrettable that the law fails to define the meaning and extent of consultation.

## III. Asserting Communities' Land Rights within the Decentralization Paradigm

Generally, community land can be considered to be the piece of land upon which local communities exercise ownership and management rights with some form of legal authority to do so, primarily driven by community benefits, sometimes directly or indirectly with the goals of sustainability.[37] Within the Cameroonian land law, this is the area generally considered as national lands which are those not classed into the public or private property of the State and or the public bodies.[38] But then, how best are national lands managed for the communities' interest especially through the decentralization system opted for by Cameroon. In this regard, the Constitution traces the decentralization system, thus, considering the State as 'a decentralized and unitary State which recognizes and protect traditional values that conform to democratic principles, human right and the law.'[39]Article 55 on its part further captures the regional and local authorities as organs apt in exercising such competences.[40]

[27] See articles 6 and 7, Ordinance No. 74-1 of 6 July 1974 on Rules Governing Land Tenure; article 1, Decree No. 76-165 of 27th April 1976 to Establish the Conditions for Obtaining Land Certificates.

[28] Article 17(1), (2) and (3), ibid; also see article 9(a), Decree No. 76-165 of 27th April 1976 to Establish the Conditions for Obtaining Land Certificates.

[29] Section 37(1) – (8), Law No. 94/01 of 20th January, 1994 to Lay down Forestry, Wildlife and Fisheries Regulations, op cit.

[30] Tamasang, C. (2007), Community Forest Management Entities as Effective Tools for Local-Level Participation under Cameroonian Law: A Case Study of Kilum/Ijim Mountain Forest. A Thesis Defended for the Partial Fulfilment of Requirements for Obtaining Ph.D. in Law. Faculty of Laws and Political Science, University of Yaoundé II-Soa.

[31] Minang, P. et al. (2019), Evolution of Community Forestry in Cameroon: An Innovation Ecosystems Perspective. Ecology and Society, vol. 24, Iss. 1.

[32] Article 16(1), Ordinance No. 74-1 of July 6th, 1974 to Establish Rules Governing Land Tenure, op cit.

[33] Reasons for consultation may vary to include: investigation for valuation, compensation upon expropriation, negotiation and for the settlement of disputes between parties.

[34] According to article 14 of Decree No. 76-166 of 27th April 1976, the duties of the Land Consultative Board shall include among other things: making recommendations to the Prefectoral Authority on the allocation of rural areas to agriculture and grazing according to the needs of the local inhabitants; make reasonable recommendation on applications for grants; examine and if necessary settle dispute submitted to it under the procedure for allocation of land certificates on occupied or exploitation of national lands; select the land which are indispensable for village communities; note all observation and all information concerning the management of national lands and transmit its recommendations to the Minister in charge of lands; examine and if necessary settle all landed property disputes referred to it by the court

[35] See article 12, Decree No. 76-166 of 27th April 1976 to Establish Conditions and Terms of Management of National ands.

[36] Article 5, Ordinance No. 74-3 of 6th July 1974 Concerning the Procedure Governing Expropriation for Public Purpose and the Terms and Conditions of Compensation.

[37] Manor, J. (1999), The Political Economy of decentralization. World Bank, Washington DC; also see, Melo, M. and Rezende, F. (2004), Decentralization and Governance in Brazil. In: Tulchin, J. and Selee, A. (ed.), *Decentralization and Democratic Governance in Latin America.* Woodrow Wilson Center Report on the Americas No. 12, pp. 37-66.

[38] See article 14(1), Ordinance No. 74-1 of 6th July 1974 to Establish Rules Governing Land Tenure; also see Melone, S. (1972), La Parente et la Terre dans la Strategie du Developpement. Klinsienck, Yaoundé and Paris.

[39] Article 1 (2), Law No. 2008-1 of 14 April 2008 to Amend and Supplement some Provisions of Law No. 96/6 of 18 January 1996 to Amend the Constitution of 2nd June 1972.

[40] Articles 55, 56, 57, 58, 59, 60, 61 and 62 of the Constitution, ibid.



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*a) Enhancing Communities' Lands Rights through Local Councils*

Given that rural Cameroonians are not secured on their lands, with national legislations seemingly unreliable, there is a need to tend to the decentralization law in other to assess if these communities and their members have avers through which their plights could better be channeled. However, given that, the national land legislations provide glimpses of right of occupancy for unregistered lands (national domain) especially those with houses and farms notably to the extent that some form of compensation is payable for loss of crops or infrastructure when the government requires the land for other purposes, it is an opportunity upon which the decentralization law could appropriate for the security of local communities. This is possible given that, the overall objective of the local authority or council is to ensure local development and improve the living environment and conditions of its inhabitants especially the communities under their jurisdiction.[41]

Furthermore, the same decentralization law accords local councils the powers to promote agriculture, pastoral, artistisanal, fish farming activities, exploitation of mineral substances that cannot be given out as concession.[42] With these competences the local councils can play great roles especially in the mobilization and orientation of local communities towards assessing landed properties for full compensation during expropriation of their lands. This can be more convenient and formal than for the members of the communities to claim in disperse ranks.[43] After all, the State has the right to grant unregistered lands in absolute title, lease or exclusive occupancy license to loggers, miners, ranchers, biofuel or food entrepreneurs or better still, to itself.[44] Granting competences to local authorities in land management might be a great step towards the transfer of responsibilities, adequate finances as well as the expectation of better service delivery on the part of local elected representatives.[45]

*b) Harnessing Communities' Rights to Land through Traditional Entities*

Pathetically, Cameroonian land laws of 1974 do not offer appropriate protection to local communities vis-à-vis their lands. This is so given that the laws appear to be passive when it comes to the recognition, protection and enforcement of communities' rights to their ancestral lands. The rather passive nature of the legislation can simply be interpreted to mean that, customary land holding does not amount to real property interests. This might be the reason why attention is rather being given in favour of private property ownership by individuals, enterprises, with the State having absolute right to evict, expropriate and lease out parcels of land in the domain of national lands. While this is so, local communities can only be compensated the' just value' of properties found on the surface of their lands and not the total value of the land and properties found both upon and underneath, including the imperceptible aspects such as customary beliefs and practices.

Moreover, customary communities and members thereof are required by the law to apply for land certificates, but this is couched upon the condition that the occupation of such land predates 1974.[46] While this is not enough, the procedure for acquiring the said land certificate is rather complicated and costly, especially given that most of these communities are poor or lack the basic means for such acquisition.[47]

From the above, it is worth mentioning that local communities could therefore rely on various consultation avers for the articulation of their rights over land. For the administration of national lands, it has been ascribed within the land legislation that, a Consultative board will be set up at the local level.[48] In this regard, the Board shall though appointed by the Sub Divisional Officer, be made up of the Sub Divisional Officer as Chairman of the Board, with a Secretary being the representative of land service of the Sub Division, a representative of the Surveys Service, a representative of Town Planning, a representative from the Ministry as well as the Chief and two leading members of the village community where the land is situated.[49] The village representatives

[41] See Section 147 of Law No. 2019/024 of 24 December, 2019 to Institute Bill on the General Code of Regional and Local Authorities, op cit.

[42] Section 156, ibid.

[43] Diaw, M. and Njomkap, J. (1998), La Terre et le Droit: Une Anthropologie Institutionnelle de la Tenure Coutumière, de la Jurisprudence et du Droit Fonciers chez les Peuples Bantous et Pygmées du Cameroun Méridional Forestier. Inades-Formation, Yaoundé.

[44] According to article 16(1) of Ordinance No. 74-1 of 6 July 1974, national lands are administered by the State in such a way as to ensure rational use and development. In this light, article 1(1), Ordinance No. 74-3 of 6 July 1974 which involve the procedure for land expropriation stipulates that expropriation will be for public purpose, a concept which is rather broad and loosely articulated to a very broad meaning.

[45] World Bank Document, (2012), Cameroon, the Path to Fiscal Decentralization: Opportunities and Challenges. The Poverty Reduction and Economic Management Report for Africa. Report No. 63369-CM; Matovu, G. (2008), Issues Relating to Developing Capacities for Effectively Implementing Decentralization Policies in Africa. Paper Presented at the Ministerial Conference on Leadership Capacity Building for Decentralized Governance and Poverty Reduction in Africa. Palais des Congres, Yaoundé, Cameroon.

[46] Article 9(a), Decree No. 76-165 of 27th April 1976 on Conditions for Obtaining Land certificates, op cit.

[47] Alden, W. (2011), Whose Land, Is It? The Status of Customary Land Tenure in Cameroon. Center for Environment and Development, Etoa-Meki, Yaoundé, Cameroon, in collaboration with FERN Office UK. P. 11.

[48] Article 16(2), Ordinance No. 74-1 of 6 July, 1974 Establishing Rules Governing Land Tenure, op cit.

[49] Article 12, Decree No. 76-166 of 27 April, 1976 Establishing the Terms and Conditions of Management of National lands.



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accentuates the views and aspirations of village community members vis-à-vis their lands.[50] From this perspective, decentralized local authorities convey the interest of local communities given that they are a reflection of the communities they represent. Here, local communities' representatives might not constitute the necessary gravitational force to argue on equal stand with State's representatives. Thus, rather than being treated as alternatives to State institutions, Communities institutions are rather being relegated to a 'ridiculous consultative body,' which point of view might not necessarily be taken into consideration when important decisions are being taken over the lands they occupy.

Moreover, local councils or communities' institutions, dispose of the right to income coming from the allocation of national lands to the share of: local councils 40% and communities or village communities obtain 20%.[51] For all these to be possible, the populations must have been consulted and invited to take part in the procedure for investigating and assessing the value of their lands.[52]

## IV. Virtues of Decentralization as Possible Avenues for Mainstreaming Communities' Land Rights

To Ribot, J.[53] decentralization is usually referred to as the transfer of powers from central government to lower levels in a political-administrative and territorial hierarchy. The main advantage of this system of power transfer is the fact that, it can be considered as a vehicle through which other competences could be transferred especially land management which stands as key determinant in local-level development. More so, the official power transfer can take two forms which include, administrative decentralization, also known as *deconcentration*, is transfer to lower-level central government authorities or to other local-level authorities generally within local communities who are however, upwardly accountable to the central government.

Nevertheless, there is political or democratic decentralization wherein authority is transferred to the representatives of local communities who are downwardly accountable actors who might be elected or not.[54]

From the above, decentralization has been considered as basic driving force for promotion of development, democracy and good governance at the local-level.[55] Hence, one could expect from this perspective, possibilities to fit within possible avenues communities land ownership and management agenda as a right notwithstanding.

*a) Decentralization Articulate the Needs and Priorities of the People*

Generally, the peoples wish in Cameroon would have been for them to have ownership over their lands, especially at the community level. To this effect, decentralization, though might not be a panacea, could just be a start to a long wished procedure to recognizing and enforcing communities rights over their lands. After all, it has been enshrined within the Cameroonian decentralization law that the State shall devolve to local authorities the powers necessary for their economic, social, health, education, cultural and sports development and that local authorities shall exclusively exercise these rights.[56]

Unlike in the land legislation where the use of national lands for public purpose goes with the consultation of the Land Consultative Board which members are appointed or already known, the local authorities are in other words voted into office and given particular mandates to fulfill the peoples aspirations, among which include land ownership. Through decentralization, a broad-base for consultation might be established. To this effect, for projects or operations to be initiated by the State on the territory of a Council, the opinion of such a council would need to be sought.[57] Such notification might not only be to acquire information, but also to bring a larger part of the community on board the decision-making process, given that such institutions are headed by elected representatives of the people or the community.

*b) Establishes Framework for the Engagement of Civil Societies*

In Cameroon, Civil Societies including Non-Governmental Organizations plays active roles especially at the basic or local level for the enhancement of Communities well-being.[58] While these organizations

[50] Among other things, the Land Consultative Board shall make recommendations for the allocation of rural areas to agriculture and grazing according to the needs of local inhabitants, especially members of the local communities.

[51] See section 17, Decree No. 76-166 of 27 April, 1976 Establishing the Terms and Conditions of Management of National lands.

[52] Tamasang, C. (2007), Community Forest Management Entities as Effective Tools for Local-Level Participation under Cameroonian Law: A Case Study of Kilum/Ijim Mountain Forest. A Thesis Defended for the Partial Fulfilment of Requirements for Obtaining Ph.D. in Law. Faculty of Laws and Political Science, University of Yaoundé II-Soa. Op cit.

[53] Ribot, J. (2002), Democratic Decentralization of Natural Resources: InstitutionalizingPopular Participation. World Resources Institute, Washington, DC.

[54] Larson, A. (1998), Democratic Decentralization in the Forestry Sector: Lessons Learned from Africa, Asia and Latin America. Cambridge University Press. Cambridge.

[55] See Section 5(2), Law No. 2019/024 of 24 December, 2019 to Institute Bill on the General Code of Regional and Local Authorities, op cit.

[56] Sections 17-19, Law No. 2019/024 of 24 December, 2019 to Institute Bill on the General Code of Regional and Local Authorities, op cit.

[57] Section 36(1) – (4), ibid.

[58] The establishment and functioning of these Organizations derive legitimacy from Law No. 99/014 of 22 December 1999, Governing NGOs and Law No. 90/053 of 19 December 1990 on the Freedom of

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operate most often at grass-root levels, their objectives which generally include the articulation of activities in the legal, economic, social, health, education, culture, humanitarian, sports, environment and human rights are found to coincide with the aims of decentralization which include that of devolving powers necessary for local economic, social, health, education, cultural and sports development. From such links, Civil Society Organizations can become more efficient in identifying and supporting the land rights of local communities if they synergize their efforts with, and channel initiatives through the decentralization pathway already engaged in the country. In this light, the government seems willing to incorporate civil societies, the private sector and other development partners in the formulation the country's long-term development vision, found to be largely hinged upon the sustainable utilization of the nation's natural resources including lands.[59]

c) *Land and Communities' Rights to Culture, Customs and Belief*

Before the intervention of the State in determining how land could be managed at different levels, local communities are generally the very first occupiers. This explains why they often tend to view themselves as owners of the naturally collective resources such as forests, rangelands, marshlands and other uncultivated lands. On her part, the State will regard such lands as unowned or State property, needing proof of human existence by way of dwellings, farming, grazing or hunting to be pre-conditions for the recognition of local communities' rights over such lands even when in their generally poor state, local communities might depend even more on off-farm resources for survival. As such, when the exercise of such rights is curtailed by the State, communities' members might not have access to farmlands to compensate for the loss of their collective lands.

Beside food, communities might depend on off-farm collective resources for cultural, customs, health and belief. While this might not be advocated for to imply only strict community based management of land, it may also be a call to include majority communities members considered to be the worst-hit by poverty in the determination of land ownership since beside the State, they can equally suffer from the inequitable class structurization in local communities with the risk of concentrated land-holding.[60] Decentralization therefore might put an end to this, while fostering local institutions with merited communities' members manning decentralized institutions at local-levels, where they will be in direct control and supervision of local developmental affairs including land.[61]

d) *Provides Opportunities for Conflict Resolution*

Certainly, local or communities' land tenure and decentralization as independent concepts might have their distinct challenges.[62] In spite of this, decentralization could if effectively implemented be a sort of panacea to local land conflicts which often end up in the relegation to a second position of customary communities' practices and belief in terms of land ownership and distribution. This aspect of conflict resolution can be effective if decentralization is legitimately considered not only to be a political market which bring together both the State and citizens as buyers and sellers of services and a means of improving service delivery, but also as a condition for local democracy and creative politics.[63]

e) *Decentralization, Harnesses Community based Natural Resources Management (CBNRM)*

The human induced catastrophes manifested through the Himalayan devastated floods, as well as the Sahelian droughts of the 70s for example helped to exposed some of the limits of the 'all sufficient' State command- and-control over land policies. While this might have helped to show the important central role of people in land sustainability, in Cameroon, it is still considered to some extent that all lands belong to the State.[64] Even so, the categorization of national lands attributing a portion to communities' occupancy can just be a first step into the recognition of the important role local communities could play as far as land management is concerned over 'unoccupied lands', though arguably superficially limited to hunting and fruits picking.[65]With these, hardly could there be a way through which land can be effectively managed without taking into considerations the role, local communities can play. The decentralization option adopted by the

Associations which is a general; law governing all forms of associations.

[59] Ministry of the Economy, Planning and Regional Development, (2009), Cameroon Vision 2035. Working Paper.

[60] Alden, W. (2012), Customay Land Tenure in the Modern World, Right to Resources in Crisis: Reviewing the Fate of Customay Land Tenure in Africa. Brief 1 of 5.

[61] Nyongkaa, K. (2020), Decentralization of Biodiversity Management under Cameroonian law: Searching for a Conservation Paradigm. American Research Journal of humanities and Social Science. Vol. 3, Iss. 12, pp. 66-83.

[62] Decentralization might be having challenges such as: lack of distinct practical limitations of the powers of the central government agencies in the control of spheres over which local communities interests prevail especially at the local level; elite capture and the over wielding of State authorities over decentralized local entities.

[63] Agrawal, A. and Ribot, J. (1999), 'Accountability in Decentralization: A framework with SouthAsian and West African Cases'. Journal of Developing Areas, vol. 33, Summer. Pp. 473-502; Manor, J. (2005), User Committees: A Potentially Damaging Second Wave of Decentralization?In: Ribot, J. and Larson, M. (Eds) *Democratic Decentralization through a Natural Resource Lens*.Routledge, London and New York. Pp. 192-213.

[64] Article 1(1)(2) and (3), Ordinance No. 74-1 of 6th July 1974 on Rules Governing Land Tenure in Cameroon.

[65] Article 17 (3), ibid.



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Cameroonian government could just be another way to democratically enforce their role.[66]

## V. Some Challenges and Difficulties Encountered in Weaving Communities' Land Rights within the Decentralization Paradigm

Through decentralization, the State is determined to devolve special powers and resources to local authorities as major driving force for promotion of development, democracy and good governance at the local level.[67] However, the content of the special powers has not been defined in the law, making one to wonder if there exist set of *unspecial powers* therein.

### a) *Difficulties in Harnessing Communities' Land Rights through Registration*

Generally, with the adoption of decentralization, the management and ownership of land would have been simplified. Arguably, this seems not to be the case given that, very modest results have been achieved to this effect so far as the government still needs to effectively support the credibility and implementation of the procedure for accessing national lands. This is so given that, the land laws in Cameroon have tended to maintain land tittle at the center of the land tenure regime. To this effect, land titles and land leases, considered to be land concessions are the legal means for the enhancement of land holding and control as right.[68]

Even with the adoption of the decentralization law, it is still considered in the Land Ordinance No. 74-1 that the State is the guardian of all lands. With this, one wonders whether the decentralized entities will be able to respond to the land needs of the populations under their different jurisdictions. As if to further encumber and render difficult the possibilities for the local communities to obtain land documents on the lands called theirs, they will need to apply for land titles by drafting development projects as a sign of human presence in other to obtain a provisional concession (*concession temporaire*). This aspect usually limits the rights communities' members may enjoy or desires to enjoy as far as unoccupied lands are concerned.[69]

### b) *Ill-adaptive Nature of Decentralized Institutions in Anchoring Devolved Land Management Powers*

Decentralization may be considered to mean different things in different context and to question if decentralization can be a panacea for Communities' land issues or whether Communities land issues can be adequately addressed by decentralization may be responded to by first of all recognizing that decentralization is layered with its own challenges. Arguably, decentralization might have been put into place in Cameroon in an attempt to resolving protracted political conflicts between central elites and those at the base.[70] And if so, one wonders if the major question of Communities land rights could adequately be resolved through this mechanism.

Developmental questions over national lands are addresses solely by the State through the Land Consultative Board presided over by the Civil Administrators (Divisional or Sub-Divisional Officers) in collaboration with traditional authorities.[71] The remarkable absence of decentralized local institutions put across the ineffectiveness of locally decentralized institutions in deciding land issues. Thus how therefore will such institutions articulate Communities land rights if they fail to be represented as members of the land Consultative Board where key decisions are taken on Communities' lands – 'national lands.'

### c) *The Receptive versus Proactive Perception of Decentralization*

In Cameroon, Decentralized Local Authorities are perceived as receivers and not proactive when it comes to issues of land management; talk less of Communities' lands. In this regard, while article 16(1) of Ordinance No. 74-1 of Rules Governing Land Tenure shies away from articulating in an express manner Local Communities' land interests, it entrusts the administration of national lands to the State – central authorities. This is further confirmed in article 1(2) of the same Ordinance where the state is placed as "guardian of all lands." While these and other pieces of national legislations seem to sap away Local Communities' rights over land, the Decentralization law seems no better. Firstly, while one may perceive decentralization as means of empowering and patronizing local initiatives, it arguably leaves one with the impression that it is limited in Cameroon to exercising 'only' the powers

[66] Section 5 (1) and (2) of Law No. 2019/024 of 24th December, 2019 on Decentralization consider that, Decentralization shall consist of devolution · by the State of specialpowers and appropriate resources to local authorities. (2) Decentralization shall constitute the basic driving force for promotion of development, democracy and good governance at the locallevel.

[67] See Section 5(1) and (2), ibid.

[68] See common article 4, Ordinance No. 74-1, July 6th, (1974) To Establish Rules Governing Land Tenure and Ordinance No 74-2, July 6th, (1974), To Establish Rules Governing State Lands; as well as article 1, Decree No. 76-167, of April 27th (1976), To Establish the Terms and Conditions of Management of the Private Property of the State.

[69] Fosting, J. (1995), Compétition Foncière et Stratégies d'Occupation des Terres en pays Bamiléké. In: Blanc-Pamard C. (ed.). Dynamique des Systèmes Agraires : Terre, Terroir, Territoire : Les Tensions Foncières. Paris : ORSTOM, p. 131-148.

[70] Diaw, M. (2009), Elusive Meanings: Decentralization, Conservation and Local democracy. Chapter 3, QXD, Pp. 56-67.

[71] Article 16, Ordinance No. 74-1 of 6th July 1974 to Establish Rules Governing Land Tenure.

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devolved to it by the central authorities.[72] Secondly, Section 28 of the Decentralization Code further reads:

(1) The powers devolved on local authorities in matters concerning public land shall be exercised in accordance with the laws in force and which is not repugnant to the provisions of this law.
(2) The State may transfer to local authorities the …property referred to in subsection (1) above, at their request, or on the initiative of the State, in order: to enable them to carry out their missions…

From the above posture, decentralization could be mistaken for command and control mechanism through which local authorities could be instructed by the central administration. In this situation the hopes mustered around decentralization as means of liberating and empowering Local Communities to beside other things articulate their land rights might take longer than expected to be a reality in Cameroon.

*d) Decentralized Authorities, Ready and/or Prepared towards Land Management for Communities' Interest*

Although the Decentralization Law in Cameroon has set the stage – the readiness for effective devolution of powers to local authorities, there still exist doubts as to whether such readiness is accompanied with the actual preparedness to hand over powers to these institutions. This can be illustrated in the land management sector as decentralized entities are yet to be granted the authority over national lands. Even if such was to be attained one wonders aloud if the interests of local Communities will actually be a major preoccupation. This might be so given that the central authority determines on which sector competence would be transferred, when and to what extent. Even so, the State still remain a major competitor among the stakeholders clamoring over national lands. In this regard, it tends to declare all lands without distinction as lands over which the government shall have management rights, especially national lands. Thus, *"…national lands shall be administered by the State…"*[73] This has casted doubts as to whether the State is actually ready to give-up this management position over lands to decentralized local authorities and whether the latter is actually prepared to take up this responsibility for the interest of local Communities they seemingly claim to represent. In Cameroon, the decentralization law is still relatively new[74] and the axes for its full implementation, especially land management for Communities interests is yet to pick up with the necessary steam.

## VI. Conclusion, Recommendations and way Forward

Building grassroots democracy arguably remains the major goal of decentralization. Such democracy when applied in land management seem however incomplete given that, local communities' interests are largely insufficiently articulated in a direct manner. Nevertheless, the full implementation of decentralization will require qualitative and quantitative trained human resources. Thus, local authorities need specialists to, beside other things, design development plans and projects for their areas, monitor implementation of developmental activities, and ensure that the daily needs of the peoples are met especially when it comes to land management and ownership. Unfortunately, it seems the National Decentralization law[75] has skipped the opportunity to articulate Communities' land interests.[76] Even so, all hope is not lost given that, in its Section 3, the law seeks to accord a 'special status' to North West and South West Regions due to among other things, their specific legal background *"…Anglo-Saxon legal background based on Common Law"*, though still awaiting a Decree of application. Thus, whether local Communities' land interests would be taken on board, is a matter to wait and see.

The devolution of power and resources to local authorities generally entails accountability. Yet, under decentralization, the State selectively determines the areas of competences to be devolved ant to what extent. While this is so, the question lingers on as to whom are the members of such local authorities accountable to, especially when it comes to communities' land ownership. Do they owe accountability duties to the local interests they represent or the State through government agents such as the Divisional Officers and Governors found to be appointed by the State with repressive powers to alter decisions taken within decentralized bodies. Thus, if this issue is not well addressed, then the effectiveness of decentralization especially in land management at the local level particularly laying emphasis upon communities wellbeing remain far-fetch.

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[73] See article 16(1) Ordinance No. 74-1 of 6th July (1974), op cit.
[74] Barely adopted in 2019. (Law No. 2019/024 of 24th December, 2019 on Decentralization).
[75] Law No. 2019/024 of 24 December 2019 on the Code to Institute the General Code of regional and Local Authorities, op cit.
[76] In its General Provision, Section 1 (2) is to the effect that the Law sets out:*"…the common provisions applicable to local authorities; the status of local elected officials; the rules governing the organization and functioning of local authorities; the financial regime of local authorities; and special regulations applicable to certain local authorities."*



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# Investigation of Formaldehyde+Hydrogen Fluoride Complex in Gas Phase by the Help of Ftir Spectroscopy and Computational Methods

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*Abstract-* High-resolution infrared absorption spectra of the H2CO•••HF complex and its monomers are recorded in a gas phase in C=O and C–H regions using Bruker HR 125 spectrometer recorded at 0.05 cm-1 resolution. After complex formation about the HF stretching band complicated shapes are not observed due to weak interaction couplings between C=O and C–H stretching of the H2CO•••HF complex. Also, quantum chemical calculations are performed in mp2//6311++g(3df, 3pd) approximation, and energetic, geometrical, and harmonic spectral parameters have been calculated.

*Keywords:* *absorption spectra, hydrogen bond, hydrogen fluoride, formaldehyde.*

*GJSFR-H Classification:* *DDC Code: 543.56 LCC Code: QD96*



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# Investigation of Formaldehyde+Hydrogen Fluoride Complex in Gas Phase by the Help of Ftir Spectroscopy and Computational Methods

Akhtam Amonov

*Abstract-* **High-resolution infrared absorption spectra of the $H_2CO\cdots HF$ complex and its monomers are recorded in a gas phase in C=O and C−H regions using Bruker HR 125 spectrometer recorded at 0.05 $cm^{-1}$ resolution. After complex formation about the HF stretching band complicated shapes are not observed due to weak interaction couplings between C=O and C−H stretching of the $H_2CO\bullet\bullet\bullet HF$ complex. Also, quantum chemical calculations are performed in mp2//6311++g(3df, 3pd) approximation, and energetic, geometrical, and harmonic spectral parameters have been calculated.**

*Keywords: absorption spectra, hydrogen bond, hydrogen fluoride, formaldehyde.*

## I. Introduction

Hydrogen bond (HB) is vital in many physical, chemical, and biological systems in life, and hydrogen fluoride (HF) is one of the strong proton donor molecule which is worthy of investigation nature of (HB). In [1] ν(HF) stretching band formation mechanisms of B···HF complexes were investigated both experimentally and theoretically in detail. Recently, computational efforts performed on the relevant complexes [2]. In [3] for $(H_2CO)_2\bullet\bullet\bullet HF$ and $H_2CO\bullet\bullet\bullet(HF)_2$ trimers accurate spectral parameters were presented through a very high level of quantum chemical calculations. Optimal geometry, harmonic spectral parameters and energetic evaluations of the $H_2CO\cdots HF$ complexes were shown in [4]. This $(CH_2O)_2$ complex has been investigated both experimentally and theoretically by THz spectroscopic and CCSD(T)-F12/aug-cc-pV5Z and MP2/aug-cc-pVQZ quantum chemical calculations [5]. In this work dissociation energy of the dimer is estimated as $D_0=13.7\pm0.3$ $kJ\cdot mol^{-1}$ for the global potential energy minimum.

Anharmonic calculations in mp2/6-311++G(3df,3pd) approximation and low temperature matrix-isolation experimental studies were performed in [6]. For the $CH_3CN\cdots HF$ complex, both experimental and computational results have showed in our paper [7]. In [8], spectral and geometrical parameters of the $[F(HF)_2]^-$ and $[F(DF)_2]^-$ complexes were performed by using the mp2 theory and multidimensional variation methods. Anharmonic calculations are play an essential role in the investigation of hydrogen bonded molecular complexes due to well agreement with the experimental results. Recently, numerous works have been devoted to solving anharmonic multidimensional problems with the help of Schrödinger equations with the variational methods [9-11]. In [12] authors utilized fully automated code for the establishing of interatomic force constants for the identification ro-vibrational spectral parameters for several HB molecular complexes. The results in the report are significantly important to analyze internal dynamics, to recognize spectral manifestation of molecular complexes, and to distinguishing overlapping spectral lines of noncovalent bonded molecular complexes.

In this work, $H_2CO\cdots HF$ complex and monomers are studied with the help FTIR spectroscopy in the gas phase and quantum chemical calculations. Obtained results are coincided with relevant literature.

## II. Experimental and Computational Methods

### a) Experimental Methods

The high-resolution absorption spectra of the $H_2CO\cdots HF$ complex and $H_2CO$ monomer were recorded with the help Bruker 125 HR spectrometer at the resolution of 0.05 $cm^{-1}$ in the gas phase. Formaldehyde molecule transferred from the powder to the gas phase by the phase changer vacuum equipment. The vacuum atmosphere has created inside of cavity cell, and the samples were placed into stainless steel cavity according to the real gas lows. The stainless-steel cavity was 20 cm in length with sapphire and ZnSe windows. Total pressure of the mixture was about 20–100 Torr.

### b) Computational Methods

Quantum chemical calculations are carried out by the help of the latest version of GAUSSIAN 16 software [15] with mp2/6-311++G(3df,3pd) approximation. Equilibrium geometries, interaction energies, and various harmonic spectral parameters of the complex have been determined.

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## III. Results and Discussion

*a) Experimental Part*

Gas phase vibrational spectra of molecular complexes yield adequate information about the rotational dynamics and complicated intermolecular interactions. Recently, in [6] the $H_2CO\cdots HF$ complex and its monomers have been studied in the matrix with the help of FTIR spectroscopy. Infrared spectra in matrix in the C=O and C−H regions were analyzed in detail. Within $2\nu_4$ and $\nu_3$ regions a new spectral features have observed.

Fig.1. shows ν(C=O) stretching region of the $H_2CO\cdots HF$ complex and $H_2CO$ molecule. In the figure, R, Q, and P branches observed. The yellow spectrum belongs to the pure $H_2CO$ molecule at pressure p=0.006 kgf/cm$^2$ (c), the green spectrum belongs to the complex recorded at p=90 Torr (b) and blue is belongs to the complex at 65 Torr (a), for all three spectra recorded at a resolution of 0.05 см$^{-1}$. Even through the fact that there were no observations of spectral changes upon the complex formation in the band, the intensity of lines increased when the pressure increased from 65 to 95 Torr. The line parameters of the band were in good agreement with HITRAN [13] database.

Intensities of the transitions can be determined through the following formula

$$S = 2.50643\nu\left[\left\langle i\left|\mu_x\right|f\right\rangle^2 + \left\langle i\left|\mu_y\right|f\right\rangle^2\left\langle i\left|\mu_z\right|f\right\rangle^2\right], \quad (1)$$

Where, S is the absorption intensity of the lines (in km/mol),i-initial state, f-final state, ν-is the transition frequency (in cm$^{-1}$), $\left\langle i\left|\mu_x\right|f\right\rangle^2$, $\left\langle i\left|\mu_y\right|f\right\rangle^2$, $\left\langle i\left|\mu_z\right|f\right\rangle^2$ - the dipole moment components (in D).

Herein the line intensities of the bands increasing when upgrade the pressure from 65 to 95 Torr, respectively.

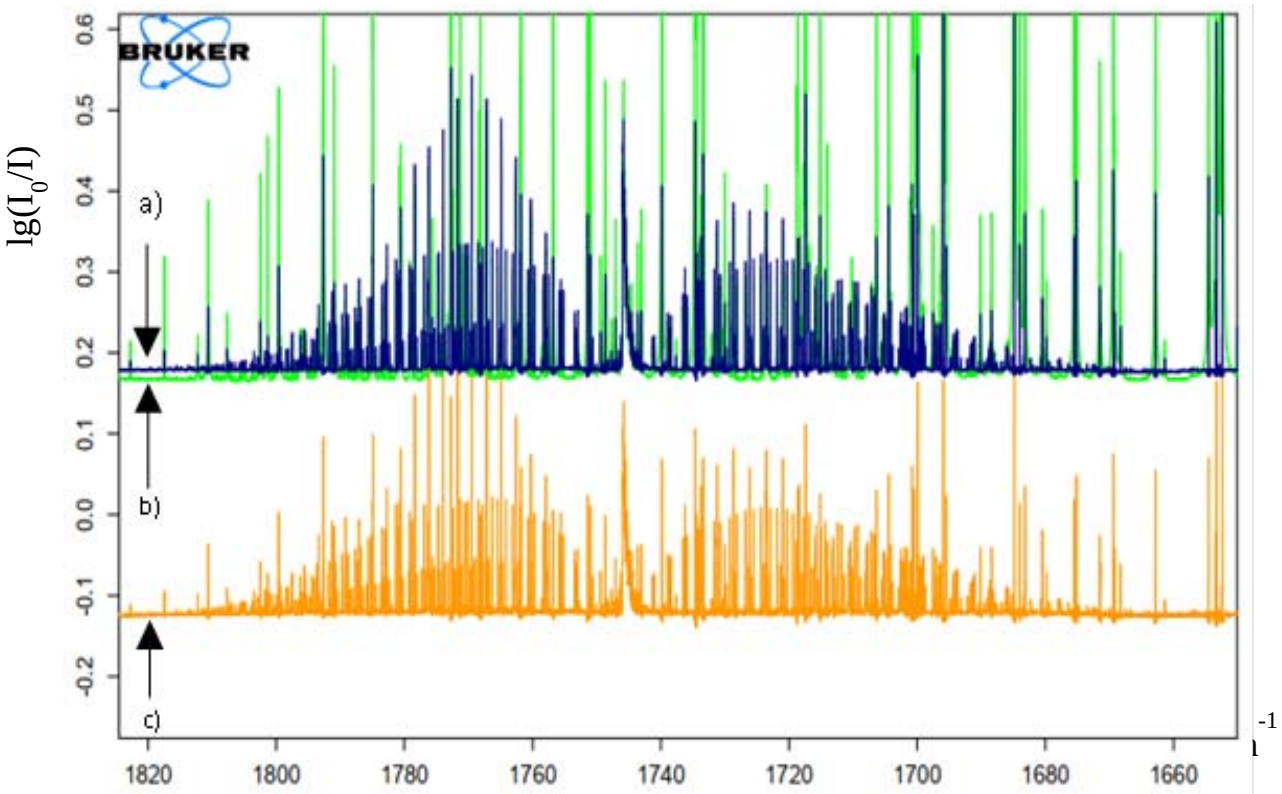


*Figure 1:* Absorption spectra of pure H2CO and HF+ H2CO complex in gas phase in the ν(C□O) stretching region. (yellow, pure H2CO p=0.006 kgf/cm2, green, HF+ H2CO complex p=90 Torr and blue, HF+ H2CO complex 65 Torr, resolution 0.05 см-1)

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All the spectral features related to the H–F, C=O, and C–H stretches and the HF librational vibrations in the $H_2CO\cdots HF$ complex.

In contrast with studied complexes in [1], in this work, the ν(HF) region is complicated spectral features are not observed upon the complex formation. Due to following reasons, complicated spectral patterns have not observed: firstly, C=O and HF stretching vibrations are weakly interacting mutually in the complex. Secondly, the mechanical anharmonic constant of the HF molecule is sufficiently large and equals 85 $cm^{-1}$. Thirdly, the $H_2CO$ molecule keeps the inclination to polymerization even in the case of low concentrations. Therefore, we are not considering the focus ν(HF) region of the complex. It requires further experimental investigations at a convenient condition and with the help of unique spectroscopic techniques.

Fig. 2. shows ν(C−H) stretching region of the $H_2CO\cdots HF$ complex and $H_2CO$ molecule. In the spectrum, R, Q, and P branches have observed, respectively. The yellow spectrum (c) belongs to the pure $H_2CO$ molecule at pressure p=0.006 kgf/$cm^2$ ,and green (b) belongs to the complex which is recorded at p=90 Torr and at blue (a) belongs to the complex p= 65 Torr, respectively. All spectra were recorded at the 0.05 $см^{-1}$ spectral resolution.

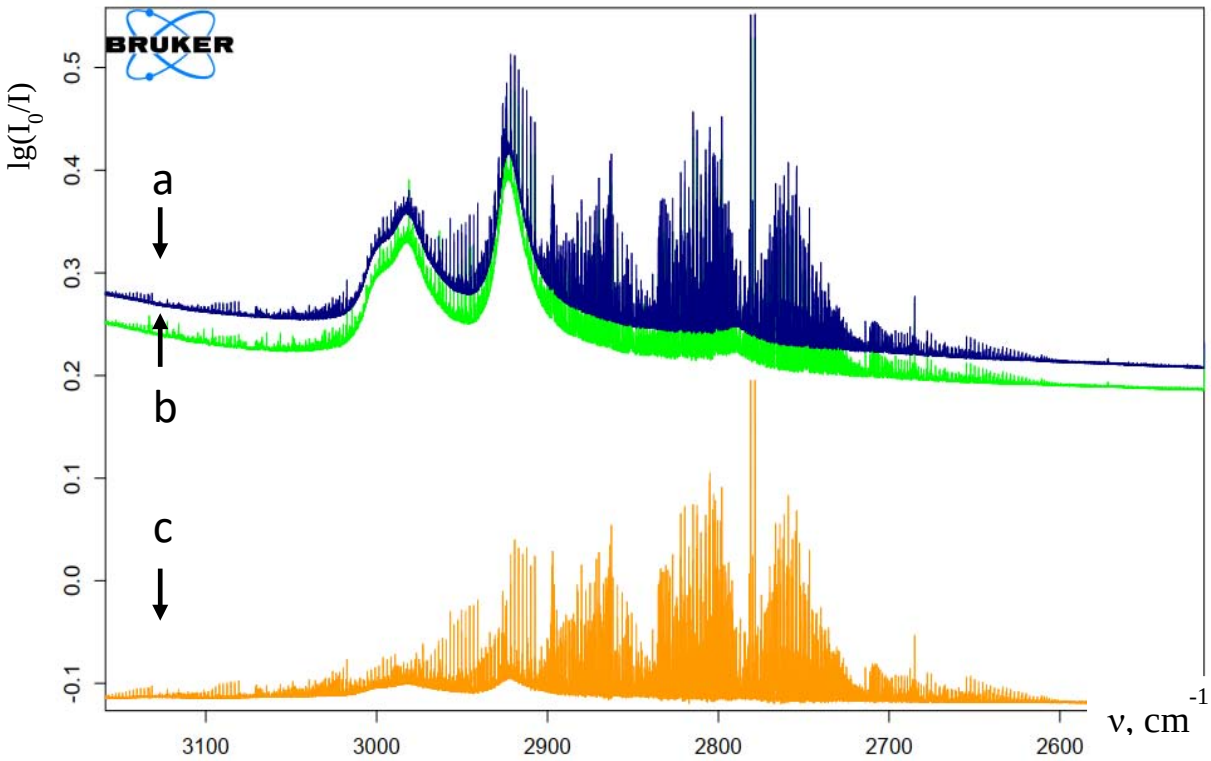


*Figure 2:* Infrared absorption spectra of pure $H_2CO$ and HF+ $H_2CO$ complex in the gas phase in the ν(CH) stretching region. (yellow-(c), pure $H_2CO$ p=0.006 kgf/$cm^2$, green (b) HF+ $H_2CO$ complex p=90 Torr and blue (a), HF+ $H_2CO$ complex 65 Torr)

*b) Computational Part*

Quantum chemical calculations on the $H_2CO\cdots HF$ complex have been carried out with using the GAUSSIAN 16 software in the mp2/6-311++G(3df,3pd) approximation with the basis set superposition error taken into account. This approximation provides accurate information for the spectral parameters of the complex. The band changes (blue or red), of the frequency, and intensity changes have been explained in [4] in detail. The equilibrium geometry of the $H_2CO\cdots HF$ complex is presented in Fig.3. Selected geometrical parameters of the complex have shown in table 1.



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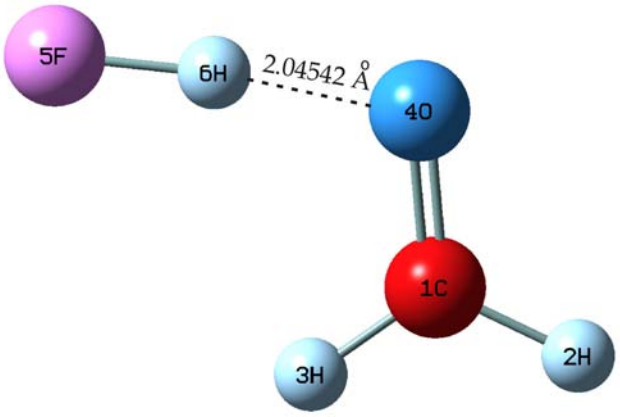


*Figure 3:* The Equilibrium Geometry of $H_2CO\cdots HF$ Complex Calculated at mp2/6-311++g(3df,3pd) Approximation

Upon the formation of the complex, H–F stretching frequency shortened by 9.89 $cm^{-1}$ and the C=O stretching band of formaldehyde also shortened about 9,7 $cm^{-1}$.

The C–H stretching frequency is blue shifted by about 39 $cm^{-1}$, and the atomic distance between C and O is increased. The H–F frequency is equal $\nu_{12}$ (3546 $cm^{-1}$) according to the computational results and this value equals to 3573 $cm^{-1}$ which is calculated in experiment [14]. The frequency of HF molecule according to experimental investigation equals to 3961.40 $cm^{-1}$. This value shifts toward to the low energy side upon the complex formation by about 345.6 $cm^{-1}$ according to quantum chemical calculation findings. Geometrical and spectral parameters of the complex are in good agreement with the calculated parameters in [6]

*Table 1:* Calculated Stabilization Structural Parameters of the $H_2CO\cdots HF$ Complex

| Distances, (Å) | Monomers | Complex | Angles, (°) | Monomer | Complex |
|---|---|---|---|---|---|
| $r(H_3–F)$ | 0.915 | 0.936 | $\angle OCH_1$ | 121.5 | 121.3 |
| r(C=O) | 1.207 | 1.215 | $\angle OCH_2$ | 121.5 | 121.1 |
| $r(C–H_1)$ | 1.101 | 1.096 | $\angle OH_3F$ | | 166.4 |
| $r(C–H_2)$ | 1.102 | 1.097 | $\angle COH_3$ | | 111.2 |
| $r(O\cdots H_3)$ | | 1.753 | ∠COF | | 141.4 |
| r(O···F) | | 2.649 | | | |

Dipole moment of the complex calculated in CCSD(T)6311++G(3df,3pd) approximations equals to 3.81D. Change of geometrical parameters upon complex formation of the complex are shown in Table 2.

*Table 2:* The Changes of the-Selected Geometrical Parameters of the $H_2CO\cdots HF$ upon the Complex Formation

| $H_2CO\cdots HF$ | | | |
|---|---|---|---|
| Interatomic distances (Å) | | | |
| Δr(C=O) 0.0057 | $\Delta r(CH_2)$ -0.0047 | $\Delta r(CH_3)$ -0.0039 | Δr(HF) 0.0186 |

In Table 3. calculated and experimental determined frequency and intensities are shown. The banding energy of the complex equals to –4.91 $kJ\cdot mol^{-1}$, and *r*(H–F) atomic distance to be 0.921 Å.

*Table 3:* Selected Harmonic Fundamental Transition Frequencies N($Cm^{-1}$) And Intensities S($Km\cdot Mol^{-1}$) and Experimental Results of the $H_2CO\cdots HF$ Complex and Monomers

| Assignments | Harmonic | | Experiment | |
|---|---|---|---|---|
| | ν | S | ν | S |
| C=O stretch | 1758 | 75 | 1744 | 61 |
| C–H in phase stretch | 3017 | 47 | 2763 | 42 |
| C–H out of phase | 3120 | 44 | 2882 | 39 |

## VI. Conclusion

In this work $H_2CO\cdots HF$ complex is studied with the help of FTIR spectroscopy and quantum chemical calculations. High-resolution absorption spectra of the complex in regions of C=O, and C-H are presented. Although, the fact that no changing reasons in ν(HF), stretching bands upon the complexation are explained.



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Quantum chemical calculations are carried out at mp2/6-311++g(3df,3pd) approximation. Dipole moment is equal to 3.81 D. The complex formation energy equals to –4.91 $kJ \cdot mol^{-1}$. A good agreement was found between experimental and computational results and the results coincide with the relevant literatures. We believe that the experimental and computational results of this work can be used to better realize the internal dynamics of the B···HF complexes.

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# Holistic Approach to Tackle (Micro) Plastic Pollution: The Case of Mauritius

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*Abstract-* There has been a drastic increase in the production and use of plastics today. Society has benefitted largely from the advent of plastics. They play a major role in our economic and social development encompassing every sector from health and food preservation, through to transportation and enhancing the digital age. Plastics have a life expectancy of many years before getting degraded or fragmented in to microplastics or nano-plastics which are easily ingested by aquatic species and eventually end-up in humans. The marine ecosystems and health of human population are severely impacted upon due to release of harmful chemicals from the latter. Moreover, since the movement of plastic wastes has no boundaries, plastic pollution is considered to a major threat to our planet. Countries around the world are having recourse to policy measures and economic instruments to counteract plastic pollution. Likewise, the Republic of Mauritius, with the main island in the south-west of the Indian Ocean, is not spared from the adverse effects of plastic pollution.

*Keywords:* *circular economy, recycling technologies, life cycle assessment, governance of plastic waste, mauritius.*

*GJSFR-H Classification:* *DDC Code: 331.28684 LCC Code: HD8051*




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# Holistic Approach to Tackle (Micro) Plastic Pollution: The Case of Mauritius

Kishore Boodhoo

*Abstract-* There has been a drastic increase in the production and use of plastics today. Society has benefitted largely from the advent of plastics. They play a major role in our economic and social development encompassing every sector from health and food preservation, through to transportation and enhancing the digital age. Plastics have a life expectancy of many years before getting degraded or fragmented in to microplastics or nano-plastics which are easily ingested by aquatic species and eventually end-up in humans. The marine ecosystems and health of human population are severely impacted upon due to release of harmful chemicals from the latter. Moreover, since the movement of plastic wastes has no boundaries, plastic pollution is considered to a major threat to our planet. Countries around the world are having recourse to policy measures and economic instruments to counteract plastic pollution. Likewise, the Republic of Mauritius, with the main island in the south-west of the Indian Ocean, is not spared from the adverse effects of plastic pollution.

In this paper, a full description of all the avenues required to beat plastic pollution, notably circular economy, recycling technologies available, life Cycle Assessment (LCA) and Governance of plastic waste (instruments) has been achieved. The current status of Mauritius in this fight against plastic waste and the implementation of these measures have also been discussed.

*Keywords: circular economy, recycling technologies, life cycle assessment, governance of plastic waste, mauritius*

## I. Introduction and Background

Plastic is cheap, lightweight, strong, pliable, and long-lasting contributing to its widespread use around the globe. In 2018, 359 million tonnes of plastic were manufactured worldwide (Plastics Europe, 2019) which are intended to be used as disposable/single use products and packaging; hence they are quickly discarded (Thompson *et al.,* 2009). Plastic waste can remain in the environment for decades. It is also easily transported by wind and water due to its low density, complicating plastic waste management.

Till now, recycling of plastics has been very insignificant (< 10%) compared to those produced (Geyer *et al.,* 2017). Most of the plastic wastes (79 %) end up in landfills or into the oceans, whereas, the remaining ones are incinerated (12%) (Geyer *et al.*, 2017). In addition, most plastics cannot be recycled several times, resulting in the down cycling rather than recycling of plastics to come up with the same type of product again. On a yearly basis, it is estimated that 4.8 to 12.7 million tonnes of plastic wastes enter the oceans, being mismanaged (Jambeck *et al.,* 2015). Other inland sources and sea sources account for another 75,000 to 1.1 million tonnes and 0.3 to 3.25 million tonnes of plastic waste, respectively (Sherrington *et al.,* 2016). Land-based sources comprise the recreational activities along coastlines, littering by the population, industry, ports and mismanaged landfills and dumps situated close to the coast, sewage overflows, accidental loss and extreme events. Ocean-based sources of marine litter are related to commercial/recreational fishing, research and military vessels as well as offshore installations such as platforms and aquaculture sites.

The other parameters which are equally important to evaluate the amount and types of plastic wastes entering the marine environment are the ocean current patterns, climate and tides, the vicinity where human activities are taking place.

Eventually, all these plastic wastes end up in gyres such as the 'Great Pacific garbage patch' (Ryan *et al.,* 2009). Ultraviolet (UV) radiation plays a key role in plastic degradation, and because UV light is absorbed rapidly by water, plastics generally take much longer to degrade at sea than on land (Andrady *et al.*,2003).

However, the rate of degradation depends on the ambient temperature as well as polymer type, additives and fillers (Andrady *et al.*, 2003). Plastic wastes break down into micro- and nano-plastic pieces, causing severe disruption in marine ecosystems and coastal communities. It also has an adverse impact on ocean health, food safety and quality, coastal tourism, and contributes to climate change. It has been reported that there are 5 trillion pieces of plastic in the oceans, with a total mass of 250,000 tonnes (Eriksen *et al.,* 2014). From this sttudy the composition of marine plastic consist of 75.4% macro-plastic, 11.4% mesoplastic, 10.6% large micro-plastics (1.01-4.75 mm) and 2.6% small microplastics (0.33–1.00 mm). The estimate by Eriksen *et al.*, (2014) of 35,540 tonnes of microplastics globally corroborates with a similar estimate for microplastics by Cozar *et al.,* (2014) of between 7,000 and 35,000 metric tonnes. When ingested, microplastics could transfer persist and organic pollutants (POPs) to marine organisms, resulting in the subsequent bioaccumulation and

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biomagnifications of these compounds in the food chain. Globally, plastic kills about 100,000 marine mammals every year (Bowker, 1986).

Thousands of additives are involved in the manufacture of plastic products (Lithner et al., 2011). Polyvinylchloride (PVC) is the polymer having the most of additives, including heat stabilizers to maintain the polymer intact during synthesis, and plasticisers such as phthalates to introduce flexibility (Lithner et al., 2011). As a matter of fact, the manufactured PVC may consist of the highest percentage of the latter additives (ca 80 %) (Buchta et al., 2005). As regards to polypropylene, a considerable amount of antioxidants and UV stabilisers are incorporated since this polymer is susceptible to oxidation (Pospišil et al., 2003). Other toxic chemicals that may be released from plastics are nonylphenol from polyolefins, brominated flame retardants from acrylonitrile-butadienestyrene (ABS) or urethane foam and bisphenol A (BPA) from polycarbonate. The rate at which these chemicals are leached from the polymers is influenced by several factors, namely the size and volatility of the additive, the migration of the polymer due to its permeability, and the temperature and pH of the surrounding matrix such as air, water, soil and body tissues (Pospišil et al., 2003).

Commonly used plastics are not prone to microbial degradation. Fragmentation and release of polymers from plastics are instead due to ultraviolet (UV) light, heat, mechanical and/or chemical abrasion (Andrady2015). Depolymerisation results from the breaking of chemical bonds along the polymer backbone (chain scission). Different polymers have different depolymeriation rates which depend on the environmental conditions such as temperature and oxygen (LaMantia 2002). Hence, it is very hard to evaluate the risks related to the exposure to plastics and their additives, given the enormous complexity and variability of the possible product combinations, their different applications and ultimate environmental distribution once thrown away. Plastic additives that are particularly harmful to human health, through the ingestion of micro-plastics via consumption of sea food, are phthalates, bisphenol A, brominated flame retardants, triclosan, bisphenone and organotins. These chemicals have the abilities to disrupt the endocrine system and also have carcinogenic properties.

Not only that marine litter is the root cause of the serious harm caused to the aquatic ecosystems and biodiversity, it also adversely impacts on the socio-economic aspect of country. As a typical example, there has been the discovery of Ecteinascidin 743, an anti-cancer drug extracted from the Caribbean sea squirt (Fleming *et al.,* 2006). It is very clear that there is still a great avenue to tap into the potential for biotechnology, bioprospecting and biomimicry and this harm to the marine ecosystems can severely undermine the quest for new nature-based solutions.

The other aspect of plastic waste is that it adds on to the economic loss through clean-up operations as well as loss of revenue from tourism and recreation activities. It can also lead to economic burdens on the shipping sector in terms of cleaning of fouled motors and 'ghost fishing' by lost and discarded nets. In view of this environmental crisis, marine litter has become a priority to tackle, being high on national, EU and global agendas. The United Nations Environment Assembly (UNEA-2) meeting in Nairobi in May 2016 came up with a high level resolution to tackle marine litter (UNEP 2016). The G7 meeting in Bonn in May 2015 has instigated member states to get firmly engaged to address plastic pollution. *Target 14.1* of the 2030 Sustainable Development Goals refers to a drastic reduction of *"marine pollution of all kinds, in particular from land-based activities, including marine debris*" by 2025. In addition, the EU Water Framework Directive (60/2000/EC) and EU Marine Strategy Framework Directive (2008/56/EC) have already introduced measures to reduce pollution and marine litter respectively. With the development of the Circular Economy Action Plan, the European Commission is now fully engaged to "*adopt a strategy on plastics in the circular economy, addressing issues such as recyclability, biodegradability, the presence of hazardous substances of concern in certain plastics, and marine litter*" (COM/2015/0614).

## II. Circular Economy

On a short-term basis, the immediate action to minimize marine litter is to improve the waste collection and management (Newman *et al.,* 2015). In the long run, a more sustainable solution is to adopt the circular economy which inter-relates three major aspects namely environmental, social and economic. A number of indicators have been postulated to monitor the progress toward the goal of sustainable use of natural resources, such as intensity of material use, material input per unit of service, ecological rucksack and ecological footprint.

Circular economy is a principle that promotes intelligent use of raw materials by allowing them circulate in the economy as long as this is justified economically and environmentally. It is one of the sectors of corporate social responsibility (CSR).Circular economy is defined as a *systems solution framework that tackles global challenges like climate change, biodiversity loss, waste, and pollution which* include material reduction, design for end-of-life recyclability, green chemistry life-cycle analyses and the use of bio-based feed stocks (Thompson *et al.,* 2009).

*Phases of plastic production comprises of four steps:*

a) The sourcing phase starts with the extraction of raw materials, namely hydrocarbons. Currently, 99 % hydrocarbons are obtained from fossil-based sources and 1 % derived from bio-based sources.

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b) The chemical phase starts with the breaking down of hydrocarbons to feed stocks needed to produce polymers and chemicals of production of plastics
c) The material phase starts with blending polymers and additives into primary plastics (pellets) and then manufacturing into final products
d) The dematerialization phase starts at the products' end-of-life, when the plastics are either recycled (18 %), incinerated (24 %) or discarded into the environment (58 %).

Upcycling processes are better aligned with the Circular Economy model, which defends that the plastic waste is a valuable resource with the potential to be recirculated in a new material cycle, as shown in Figure 1 below:

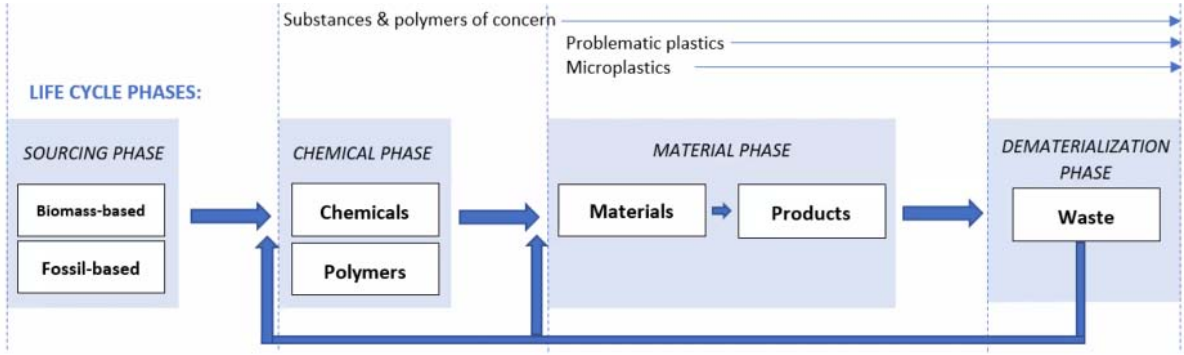


*Figure 1:* Plastic Waste Being Recycled

If focus lies in the downstream production of plastics, greenhouse gas emissions will still be significantly released. For greater carbon savings, upstream actions are urgently required to tackle the problem at its root. Examples of such actions are designing out waste, to avoid its generation and to reuse products. Also, recycling replaces raw materials at a much lower carbon cost and thus reduction in the emissions across the economy is achieved. To ensure the highest number of cycles, products, components and material should be kept at their highest utility and value (Weigend et al., 2020). However, this is not the case in the recycling business since upcycling processes are more complicated, and energy/resource-intensive.

Consequently, the environmental benefits of plastic upcycling are often put into question and down cycling methods are instead approved because of their lower complexity and costs, irrespective of the permanent and loss of quality.

The EU Action plan for the Circular Economy (COM/2015/614) has come up with the Strategy on 'Plastics in the Circular Economy'. The following circular economy tools can be adopted to retain plastic and its worth in the economy and out of the ocean:

- *Extended Producer Responsibility:* Use EPR to avoid certain types of marine litter, most notably single-use packaging items.
- Research into product design to facilitate reuse, repair, remanufacture and recycling, and complement this by providing more information on the plastic composition of products.
- Bans for unnecessary and damaging products or activities where viable substitutes exist - e.g. plastic microbeads in cosmetics can be replaced by ground nut shells, marble particles or naturally-grown polymers, and plastic blasting in shipyards can be replaced by ultra-high pressure water jets.
- *Improved legislation:* Provide clear definitions of polymers, waste and secondary raw materials. Manufacturers need to design their products and packaging to fit into existing recycling systems.
- *Economic incentives targeting consumption:* Make greater use of economic incentives to make market signals part of the solution - i.e. ensure that plastic has a price and is therefore more widely recognised as a valuable resource – e.g. apply deposit-refunds to bottles, and charges/taxes to plastic bags, disposable cutlery, and other one-use items.
- *Transparency and labelling:* Improve transparency on the chemicals contained in plastics – to help with decisions on remanufacture and recycling. In addition, transparency on where personal care and cosmetic products do and/or do not contain plastics. Explore the implications for additives such as flame retardants, plasticisers, pigments, fillers, and stabilisers.
- *Waste management measures:* Invest in waste collection infrastructure and services (at ports), waste management infrastructure and wastewater treatment facilities to avoid dispersion of litter into the marine environment - particularly in coastal areas or near rivers.
- *Awareness-raising:* Raise awareness among consumers to improve waste disposal (littering and waste separation), and also better inform purchasing habits to increase demand for sustainable substitutes - e.g. cosmetic products not



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containing microbeads (e.g. via Beat the Bead), multiuse bottles and bags, purchase of washing machines with filters.

In addition there are two further useful measures beyond the Action Plan

- *Fishing for litter:* combined incentives to encourage action, and develop new products from waste. While this is not the most cost-effective of solution (efforts higher up the hierarchy are preferable), it can create interesting branding opportunities for manufacturers, raise awareness and contribute to reducing pressure on the marine environment in selective places.
- *Improved implementation:* In addition, there is a need for better implementation of existing legislation on the release of litter, from terrestrial sources and at sea – e.g. The MARPOL Convention, Waste Framework Directive, Directive on Port Reception Facilities, Water Framework Directive and, Marine Strategy Framework Directive.

In the action plan, opportunities to look closely at plastic pollution at all stages from production till disposal are elaborated below (Table 1).

*Table 1:* Opportunities in the EU Action Plan for Circular Economy

| Section (pages of action plan) | Issue | Opportunity |
|---|---|---|
| Plastics (pp. 13-14) | Strategy on 'Plastics in the Circular Economy' (2017)-The Commission will adopt a strategy on plastics in the circular economy, addressing issues such as recyclability, biodegradability, the presence of hazardous substances of concern in certain plastics, and marine litter. | This is the main opportunity to ensure that circular economy measures to address marine litter are noted. Essential for stakeholders to contribute to the consultation and ensure key initiatives feature in the |
| Product Design (p.4) | Promote the reparability, upgradability, durability, and recyclability of products by developing product requirements in the Ecodesign Directive (2016 onwards)<br>Create economic incentives for better product design through provisions on extended producer responsibility (COM/2015/595) | Offer upstream solutions that can reduce single-use or short life time products that could or are known to contribute to marine litter |
| Production processes (p.5) | Inclusion of guidance on best waste management and resource efficiency practices in industrial sectors in BREFs (e.g. Food Drink and Milk Industries; Production of Polymers; Surface Treatment of Metals and Plastics) (2016 onwards) | Key aspects here relate to the extent that plastics can be recycled, and the quality of recycled plastics. Exploring for example the impact of additives such as flameretardants. |
| Consumption (p.8) | Revised waste proposal will provide new rules which will encourage reuse activities (COM/2015/595).<br>Possible use of Product Environmental Footprint to measure and communicate environmental | Engage and provide opportunities for behavioural change, which allow<br>consumers to close the loop on plastics. |
| Waste management (pp.8-11) | Revised waste proposal: recycling 65% of municipal waste by 2030; recycling 75% of packaging waste by 2030; to reduce landfill to maximu of 10% of municipal waste by 2030; a ban on landfilling of separately collected waste; promotion of economic instruments to discourage landfilling; simplified and improved definitions and harmonised calculation methods | Improved recycling reduces the risk of waste becoming marine litter. Implementation of waste hierarchy, see Figure<br>2. Plastic is a formally recognised target area so relevant action easier to promote. |
| From waste to resource(p.13) | Develop quality standards for secondary raw Materials-in particular for plastics. Improve rules on 'end-of-waste'(2016onwards)<br>Develop analysis on the interface between chemicals, products and waste legislation (2017)<br>Develop the Raw Materials Information System | Provides an economic argument for closing the loop. There is a need to help develop the market by providing information,<br>awareness and legal clarity. |



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| | | |
|---|---|---|
| Innovation, investment (pp. 18-20) | Horizon 2020 WP 2016-2017 – Industry in the Circular Economy, with funding of over EUR 650 million (Oct 2015 onwards) Pilot 'innovation deals' - to address regulatory obstacles to innovators (2016)<br>Step up action to mobilise stakeholders in the circular economy, as well as targeted outreach to develop circular economy projects through Cohesion policy funds….[inc.] are of plastic recycling (2016 onwards)<br>The global dimension of the circular economy and supply chains is prominent in areas such as | Can catalyse the development of the circular economy and hence keep plastic and its value in the economy.<br>Research objectives and knowledge gaps should also be considered. |
| Monitoring (p21) | Monitoring framework for the Circular Economy to be developed with the EEA (2017) | Monitoring of marine litter, and also level of plastic reuse and recycling will be helpful indicators of circular economy developments |
| SDGs (p 3) (p13) | This action plan will be instrumental in reaching the Sustainable Development Goals (SDGs) by 2030, in particular Goal 12 of ensuring sustainable consumption and production patterns.<br>Specific action to reduce marine litter implementing the 2030 SDGs target p.13 | The EU has made global commitments to addressing marine litter (which is a cross border issue) – engagement and collaboration internationally is important. |

Furthermore, the roadmap for plastics, marine litter and circular economy is also laid out in the action plan which describes the roles of stakeholders concerned and their responsibilities. From the latter, it can be noted that this crisis can be addressed by engaging in public awareness campaigns about the adverse effects of marine plastic pollution, providing governments with tailored and specific knowledge on appropriate public policy measures, and capacity building and mobilizing a wide range of stakeholders from the private sector, the research community, NGOs, local authorities, and national governments. Women, youth, and coastal communities can also participate actively to bring the expected changes to an extent to make a difference. Tackling the problem of marine litter through circular economy not only offers clear benefits for the aquatic ecosystem, but also take into account the depletion of natural resources and climate change. It also has the potential to create jobs and to foster innovation and market creation (Ellen MacArthur Foundation, 2016). As a concrete example, a joint project based on circular economy initiatives involving South Africa, Mozambique and Kenya, Thailand and Viet Nam over three years 2017 to 2020 revealed that an appreciable reduction or diversion of plastic to the oceans had been achieved. In fact, more than 240,000 kg of plastic was denied from reaching the ocean in the five countries (Boucher *et al.* 2020). Moreover, the technical and financial support from the project provided capacity building to the grantee entities. This was noted in Kenya and they were able to invest in machinery for plastic crushing and processing. In Thailand, the circular economy initiative grantee, Jan and Oscar Foundation became the country's first entity to be awarded the Ocean Bound Plastic (OBP) certification. The OBP Certification Program was established by the NGO Zero Plastic Oceans together with the certification group Control Union to protectoceans from the continuous leakage of Ocean Bound Plastic (OBP) from land-based activities. The Program is intended to contribute significantly to the removal of OBP from the environment by adding value in effectively collecting and treating it before it reaches oceans.

The circular economy initiatives were also found to contribute significant towards poverty reduction and bestowing dignity of those engaged in the lowest rungs of the waste value chains, for example, waste pickers. In particular, the sponsored circular economy initiatives resulted in capacity development of community groups, and income generation for vulnerable women and youth through participation in the waste value chain, such as collection and recycling activities.

## III. Recycling

As mentioned above, plastic wastes can cause severe harm not only to the ecosystems, but also to the environment (Gall and Thompson, 2015) owing to the continuous production of virgin fossil- based plastics, leading to depletion of natural resources and excessive release of greenhouse gases during the production phase, the transport of materials and incineration of plastics as a disposal method. Without value retention,



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the value from plastics in terms of material and embodied energy is lost. With more recycling, less dependence on the natural resources can be attained while meeting raw material demand. At the same time, lesser emissions and pressure on the fragile ecosystems can be achieved (Ellen MacArthur Foundation, 2013). For plastic to become a circular material, the current recycling rate has to be increased drastically. Plastic packaging from municipal waste is most recycled, whereas plastic recycling from the construction, electronics and automotive industries needs to be improved (Consultic, 2012). Additionally, to ensure re-use in products, emphasis on the production of high quality recycled plastics has to be laid upon. (Hahladakis and Iacovidou, 2018).There exists a wide array of commercial and innovative recycling technologies for plastic recycling.

*Typical examples are:*

- Clothes are made from synthetic materials. Microplastic fibres released in washing machine wastewater end up in wastewater streams. A plausible solution is to install a commercially available filter to trap these microfibers.
- Plastic Whale is a social company located in Amsterdam which has an exemplary way of taking care of plastic wastes. It would pick up those floating plastics along the canals. After sorting, PET bottles are recycled and the new materials obtained are used to make canal boats. Individuals, groups and companies would then fish for plastics on the boats and the process is repeated to make more boats. Up to now, Plastic Whale has built seven boats from 35,000 bottles. This initiative plays a key role in creating awareness and stakeholders are fully engaged to counteract the marine litter problem.
- In 2015, two enterprises, Adidas Group and Parley for the Oceans, have joined hands on a long-term project to come up with measures against plastic pollution of the oceans. They are investing in research and innovation and at the same time they want to create awareness through education and communication. Part of the collaboration consists of creating innovative products from materials produced from plastic waste that would serve as fabrics for Adidas products (Ten Brink *et al.,* 2016). Initiatives such as these can lower unemployment rate and create new markets for recycled plastics. They should, however, be considered as one aspect to bring a solution to the bigger problem since priority should be to prevent the generation of marine litter.

There is a general hierarchy available for plastic recycling, based upon the extent to which the polymer stays intact, which overlaps with the inner (material remains intact) and outer loops (material not intact) of the circular economy (Ellen MacArthur Foundation, 2017) which is depicted as follows (Figure 2):

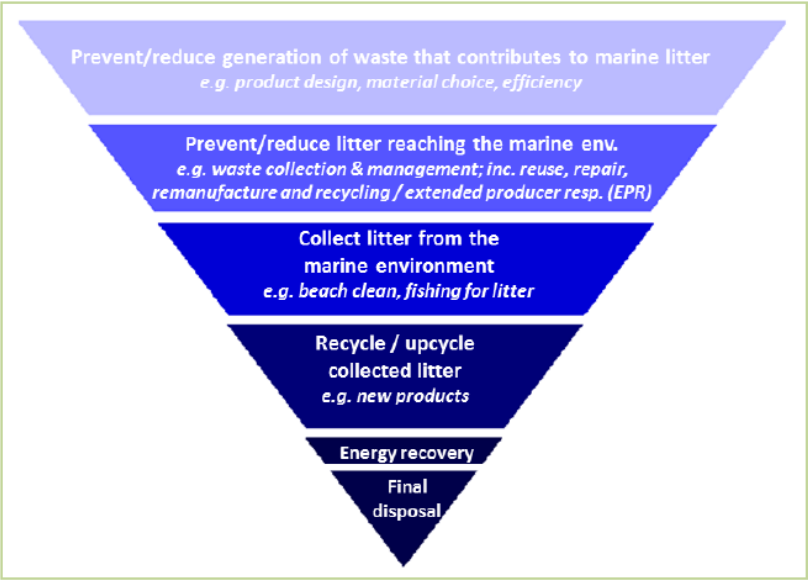


*Figure 2:* A Hierarchy for Marine Litter Management

From Figure 2, prevention of wastes should be highly encouraged. Most importantly, recycling relies on two features of segregation. The first is the concentration of different elements or materials within a product after mixing which can be determined through design for recyclability. The second is to sort out the wastes at the point of generation such that they are collected clean and uncontaminated by other waste streams.

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The recycling technologies fall into four groups of the recycling hierarchy (Singh *et al.,* 2017; Vollmer *et al.,* 2020) namely

- Primary recycling (most intact) or closed-loop recycling refers to the recycling process where the material can be recycled to into products with similar properties, hence the plastic polymer is kept circulating in the same 'loop'. Primary recycling takes place for pre- and post- consumer (mono-stream) plastics. This process of recycling can only happen when plastics are not mixed with other interfering materials or polymers.
- Secondary recycling or open-loop recycling refers to the recycling process where the material can be recycled but the products are of lower quality than the virgin material, hence the latter are used as a lower value product and recycled in an 'open-loop'. Currently, most consumer plastic recycling follows this route. The plastic waste contains a significant amount of contamination due to presence of other chemicals such as additives.
- Tertiary recycling involves the conversion of plastic to feedstock and plastic to its initial monomer. In this case, the polymer is chemically modified, making sure that the valuable materials (feedstock, monomers) are being recovered. The polymer serves as a discarded material with the possibility of being converted into products such as syngas ($H_2$/CO molar ratio of 2:1), waxes, diesel, new polymers.
- Quaternary recycling (least intact) or incineration of plastic material with energy recovery. During its incineration, there is recovery of energy as heat and electricity. The amount of heat and power depend on the calorific value (energy content) of the polymer and the efficiency of the waste-to-energy plant.

Primary recycling offers the best avenue for recycling (inner loop) whereas quaternary recycling (outer loop) the least (Singh *et al.,* 2017). Nowadays, mechanical recycling plays the most important role in plastic recycling, and is categorized as secondary recycling ('open-loop' recycling) where the plastic is down cycled to be only partially re-used for the same purpose due to quality reduction (Ragaert *et al.,* 2017; Sheppard *et al.,* 2016).

The quality and quantity recycling gaps is due to the collection of plastic waste in a mixed stream, having different polymers and even objects (metals, cardboard, rubber and so on). Furthermore, plastic products consist of about 30,000 chemicals, including multilayer material, copolymers, stickers, fillers and additives, which complicate the recycling process (Hopewell *et al.,* 2009). However, there are alternative, innovative recycling technologies that address these shortcomings associated with the plastics from different waste streams. In particular, tertiary recycling allows plastic waste to be recycled to monomers or feed stocks with thermochemical methods (Vollmer *et al.,* 2020). Chemical recycling options can also be considered; a process in volvingde polymerization where polymer bonds are broken through the use of chemicals, or dissolution with solvents while maintaining the polymer backbone (Vollmer *et al.,* 2020). However, little is known in terms of the environmental impacts of these existing or innovative recycling technologies and consequently, it is difficult to determine which technologies are most appropriate in a circular economy.

## IV. Life Cycle Assessment (LCA)

On the other hand, through Life Cycle Assessment or Life Cycle Analysis (LCA), the environmental impact of a product or technologies can be assessed over the course of its entire life. Life cycle management tools can contribute to the building up of a circular economy business model (Zinck *et al.,* 2018*;* Avesani*,* 2020*)*. Application of LCA in the circular economy has been comprehensively described in literature (Kambanou and Sakao 2020).It is reported that the adoption of LCA can indeed contribute towards sustainable policy making and determine which technological innovations can provided the best solution to improve sustainable businesses. LCA also serves as a method to find the optimum product, service, or other solution, at some point in time and in regards to specific environmental effects, such as carbon emissions.

Current LCA studies on plastic recycling are carried out to evaluate the positive environmental impact of a recycling technology against the present situation. The recycled polymers are termed as 'avoided virgin polymer' and are assigned a negative value as part of the environmental impact assessment, resulting in a 'positive' contribution (Gu*et al.,* 2017). However, like any tool, it has its drawbacks where misleading or contradictory outcomes can be generated, therefore can not validate a circular economy model. The reason is that only a single recycling technology is taken into account, or only a specific waste stream (packaging or municipal plastic waste) (Chen *et al.,* 2019; Gu*et al.,*2017). In addition, LCA studies can only be carried out with existing boundaries of waste stream on a short-term basis. System boundaries between polymers and recycling technologies involved in the LCA studies include polymer granulate production, recycling treatment impacts and avoided products. For a circular economy, systemic change needs to be considered which is on a long term basis. Other factors that should also be taken into account in these studies are product type, sector, and waste collection method. Thus, comparability cannot be achieved and eventually there is no possibility for scale up or to use the results in



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another context (Astrup *et al.,* 2015). Also, LCA can often ignore impacts that pose a challenge to measure or less well understood, such as plastic in the environment or the long term effects of landfill runoff. Hence, one has to be cautious when applying Life Cycle Analysis.

*Life Cycle Assessment also provides means to:*

*a) Investigate the Effects Of varying External Parameters*

Life Cycle Assessments can be used to study the effect of external parameters that might change between geographies or with time, in particular to the implementation of recycling industry or adoption of a latest technology. This can be achieved by modifying the input parameters of an LCA model.

*b) Compare Similar Outcomes*

Results obtained from LCA are reliable as far as the other components of the system do not vary significantly. For instance, LCA could provide a good comparison of the carbon emissions of two different packaging material selections, given that the other components of the business model remain unchanged.

*c) Apply LCA in Later Stages of Innovation*

An LCA is most trustworthy when accurate and validated data are at hand and that there are not many unknown variables. Once the flow of materials and resources within the infrastructure is established, an LCA can be very powerful. Innovation stages include scaling up or improvement of an existing system. These stages would constitute the best time to perform LCAs. However, caution should be observed when applying LCA in the early stages of an innovation process.

## V. Governing Plastic Waste

Each governance context includes a multitude of actors, namely the governments, companies, NGO's, entrepreneurs, citizens and so on. Each actor has its own understanding of the problem, its own viewpoint on the social environment, its own opinion about what should happen, and its own interests at stake. In order to understand the role and position of these actors a very clear and comprehensive institutional framework within a particular context should be set up. This institutional framework shapes and coordinates the actions and interactions of the different actors. The institutions are the rules of the games that include for example policies, laws, plans, and rules of conduct.

These rules for example define which organizations are responsible for waste management or they regulate the production and use of particular plastic product. Designing and implementing policies and laws are important means to deal with plastic pollution, but it is also important to understand who is able to introduce new policies and to analyze how and if particular legislation is indeed enforced.

Governments also devise and enforce the institutional context in which markets are created and are operating. The importance and role of governments and their institutions can, however, hugely vary between countries and among sectors, issues and levels within a particular country. Some countries have implemented an elaborate set of policies and laws to manage waste and succeed fairly well in enforcing laws, while others lack resources or political will to do so. Some governments might be very active in stimulating economic growth, but largely ignore the environmental problems that come along. Some prefer steering by law, others via policies and planning, or through economic incentives. Some governments are more concerned with plastic pollution, while others think that this is an issue that should be solved by societies or businesses. And all this is subject to change over time. There is a wide choice of measures that are available to tackle plastic pollution which are research and development at the different stages of plastic production, policies (bans, EPR), direct investments (capacity building in terms of recycling and waste management systems), market-based instruments (deposit-refund schemes or product charges), awareness-raising initiatives(campaigns and mobile apps) and clean-up activities.

*The choice of the most suitable measures can be achieved by the following:*

- Identifying the problem; context and objectives
- Performing a risk assessment, to identify the nature of the risk and justify the action to be taken;
- Prioritizing the component(s) of the DPSIR model (Driver, Pressure, State or Impact)
- Designing the most suitable plan

Across all these stages, a mechanism has to be set up for consultation and communication, and a system to evaluate the risk and consequences of applying a particular measure.

*Existing measures consist of:*

- Extended Producer Responsibility approach by encouraging the producers, manufacturer brand owners and importers to follow the product throughout its entire life-cycle by adopting measures high in the hierarchy of waste management to be able to come up with products for reuse, recycling and materials reduction in terms of total mass and toxicity;
- Sustainable Procurement Policies to allow for the use of recycled plastic-made materials;
- Encouraging voluntary agreements with retailers and supermarkets to bring a decrease in the amount of plastic bags utilised and /or introducing plastic bag taxes
- Enforcement of laws in regards to mandatory Deposits, Return and Restoration System, especially

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for beverage packaging such that the latter can be reused.

*There are sixteen multilateral instruments which are very useful and they are grouped in four clusters:*

- Binding instruments directly governing chemicals in plastics (Stockholm convention, Montreal Protocol, Minamata convention, Rotterdam Convention, ILO 170).
- Binding instruments directly governing aspects of life cycle of plastics (Basel convention, MARPOL Annex V, London convention, London Protocol).
- Binding framework agreements of relevance (UNCLOS, CBD, UNFCCC, Paris Agreement).
- Non-binding multilateral instruments of relevance to chemicals, wastes and plastics (UNEA, UNGA; Resolution 70/1 on the 2030 agenda, SAICM).

*a) Characterizing Actors and Approaches: State, Market and Civil Society*

Although state, market and civil society are in the first place different entities, it is important to realise that many organizations, approaches and governance structures have overlapping features. Furthermore state, market and civil society are strongly related and are exerting influence on each other, and the role and performance of either of them cannot be made clear without considering their common grounds towards each other. Creating a platform, for example a discussion forum, where these three entities can meet on a regular basis, will allow the identification of gaps and shortcomings in the current situation and to develop additional and novel approaches and instruments. A stakeholder analysis is a useful method to obtain further insights in the importance of particular actors and their role in managing plastic waste. Analyzing stakeholders is also useful for designing and selecting effective strategies through which various actors can be approached and stimulated to change their actions or decisions. The stakeholder analysis could for example be used to develop a communication strategy.

*b) Strategies for Change*

The different actors concerned can launch campaigns to create awareness and drive political will, they can initiate clean-ups, conduct research and monitoring, establish new policies and laws or amend existing ones. The main goal of many strategies is to bring a change in the mindset of people at different levels such that actions can be easily undertaken.

Education and outreach are key to drive the chosen strategies. One can think of the need to raise awareness about plastic pollution among consumers and citizens and among public and private organizations, or of different ways in which civil society can be mobilized to protest and demand action. But raising awareness by itself will not be sufficient. Therefore there are other strategies that actors can carry through to realize new policies and different ways of producing, using and managing waste.

Most actions require the involvement of other actors, and sustainable solutions mainly emerge from a national/international network of actors. To achieve collective action one needs to convince other actors such as individuals or organizations, to join a network and collaborate to tackle plastic waste. Such collaboration needs to be initiated and a network of actors needs to be built and coordinated. Successful actions therefore not only require assembling teams and networks, but also managing them.

These different strategies to bring change can be categorised into four groups (Brouwer and Biermann 2011) which are attention- and support-seeking, linking, relational management and arena strategies. As mentioned above, whether particular strategies are useful and successful depends on the time and place in which they are deployed, and on how they are designed.

The '4Es' framework (Zamriet al., 2020) for designing initiatives to change people's behavior consists of four complementary elements which are Enable (make it easier), Engage (get people involved), Exemplify (lead by exemplify) and Encourage (give the right signals). To draw people's attention and to heighten their interest, it is essential for social instruments to take as a starting point the 'sense-making' of the citizens and their realities- their lives and surroundings. Information on its own is not enough to create the much needed and lasing change in people's mindset. Both information and instruction are required to work hand in hand to be able to get people actively involved. Adopting new ways of behavior should be highly encouraged without compromising their freedoms is a challenging task, with possible political implications.

Being versatile with social marketing will definitely help in the design of tangible activities from the array of social instruments. However, this is perhaps not the case in a waste management facility. This is the knowledge that engineers and public health officials in the field of waste management should acquire and is conceived from sociology, social psychology, evolutionary psychology, cognitive neurosciences, and other related fields that corporate marketing often employs for its commitments.

In addition, the general public can be made aware about the producer's involvement in an approved recovery scheme, such as the 'Green Dot' scheme for packaging, which has been devised and implemented in Germany (Rousso and Shah, 1994). The 'Green Dot' logo on packaging notifies that the producer is meant to pay a certain fee to the national organization for packaging recovery that has been imposed according to the European Packaging and Packaging Waste Directive 94/62 and the respective national law. It is noted that organizations in 28 countries have adopted



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the Green Dot as a financing scheme to promote the collection, sorting and recovery of thrown away (mainly household) packaging.

Many initiatives are taken by local action groups such as beach clean-ups or river shores. But also business and governments throughout the world are taking actions, at local, national, regional or global level. Tackling the problem of plastic wastes requires coordination of policies and practices at sea, along the coast, in riverine systems and on land. The design and implementation of effective, efficient and legitimate actions and strategies should be based on a thorough understanding of the governance context that one aims to change (Van Assche *et al.,* 2014). Understanding the different perspectives of the actors involved is key to get them fully engaged. Furthermore it is important to know that policies and legal institutions to prevent pollutions are more successful in one context than in another for example because of different enforcement mechanisms (Carmen *et al.,* 2015). Still, successful approaches in one place can be inspirational to initiatives elsewhere.

For example, the introduction of a tax in 2002 on plastic bags in Ireland triggered similar initiatives in other countries (Madara *et al.*, 2016). On the other hand new policies and laws can inspire local initiatives, companies, and scientists to tackle the plastic issue by, for example, developing sustainable products and processes. Companies can be inspirational by showing that sustainable products and production processes are feasible and can persuade governments to address the need of collaborative action. Governments can facilitate local actions, introduce policies, laws and plans, improve waste management systems, stimulate enterprises to produce in more environmentally responsible ways, and finance scientific research that improves our understanding of the problem and that helps to develop sustainable solutions.

## VI. Where Does Mauritius Stand?

Mauritius Island is situated in the south-west of the Indian Ocean and is a famous tourist destination. The land area of the island is about 1865 $km^2$ with a population of about 1.2 million (Statistics Mauritius 2021). In Mauritius, waste segregation at source is not a common practice and therefore household and commercial wastes are disposed of without being segregated. The wastes are collected regularly at least once weekly by the local authorities which are dumped at Mare Chicose, the only sanitary landfill site. However, in 2021, the government has built its first facility where wastes get segregated into electronic wastes, green waste, plastic wastes and glass.

In 2020, about 75,000 tonnes of plastic wastes were generated (SM 2021a), corresponding to14.5% of the yearly municipal waste. It is noteworthy that there had been an appreciable increase in municipal wastes from 8 % in 2000 to 14.5% in 2020, following the discard of single-use plastic products. The different types of plastic polymers present in the plastic waste in Mauritius include high-density polyethylene (HDPE), polyethylene terephthalate (PET), low-density polyethylene (LDPE) and polystyrene (PS).Plastic recycling is still at its infancy stage. In 2020, only 3000 tonnes of plastic were recycled(SM 2021a), mostly PET bottles.

### *a) Actions Taken to Tackle Plastic Pollution In Mauritius*

The Government of Mauritius came up with some regulations/incentives to reduce the use of plastics, especially for single use plastic products and PET bottles, with the following chronological order:

- Enforcement of the Environment Protection Regulations 2004 with the goal to forbid production and import of non-degradable plastic bags with gussets and handles with a wall thickness of less than 20 microns.
- An excise duty was imposed on plastic bags with gusset and handles in 2006 to cut down the proliferation of plastic bags
- Doubling of excise duty in 2010 to urge users to instead use thicker and reusable bags
- Enforcement of Environment Protection Regulations 2015 to prevent the use of plastic bags with or without gussets and handles
- Enforcement of Environment Protection Regulations 2020 for Hyper-markets and commercial centres to have recourse only to biodegradable bags
- Promulgation of Environment Protection Regulations 2020 was imposed on restaurants, snacks, supermarkets and hotels to make use of biodegradable products derived from plant-based materials such as starch from corn/potatoes, bagasse, palm leaves and poly lactic acid

Despite these measures, importers and local manufacturers were freely distributing non-biodegradable plastic bags *without* handles to sell their products, leading to an increase in the consumption of these plastic bags. It was only, in 2020, when the government brought into force of the Environment Protection (Banning of plastic bags) Regulations 2020 that the measures were taken seriously since fines and even imprisonment would be imposed. The regulations prohibit the use, import, production, sale and distribution of petroleum-based plastic bags, except when authorised. As it stands, ten single-use plastic products such as cups, spoons, forks, knives, straws, bowl, trays, hinged containers, stirrers and lids/covers have been prohibited. Possession of any of the latter is illegal, and the offender is liable to pay a fine and can even get sentenced in court.

Despite these regulations, it can be observed that small enterprises like shops are still making use of the prohibited plastic bags. The latter are acquired from

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an illegal network of providers which is hard to track down through the existing enforcement actions. It was also noted that there are even fake biodegradable plastic bags that are being distributed and/or sold. On the other hand, industries dealing with milk products and those requiring modified atmosphere packaging (MAP packaging) are against the substitutes being provided for their current plastic products since they do not meet their requirements. They have thus requested an additional moratorium period (up to 2023) to be in line with the regulations.

Besides regulations, Mauritius, though it is not involved in the manufacture of plastics, has to invest in research and innovation to address plastic pollution. The immediate challenges are to identify the point/ /non-point sources of pollution. Carrying out LCA would definitely lead to a better understanding of the plastic life cycle under varying conditions. In the plastic industry, sustainability should be the key issue to take into account at all cost. One such avenue is to abide by standards such as the Reporting Initiatives (GRI) (GRI 2021), and the Green Globe sustainability certification (Ásványi, 2021). The latter encourage the use of sustainable products and deal with important sectors such as tourism and manufacturing to become not only profitable, but also environmentally-friendly.

To promote circularity of plastics in Mauritius value chains from manufacture to end users have to be studied. Currently, the flow of plastics in Mauritius is linear, from cradle to grave approach. However, it is imperative to develop a roadmap where circular economy together with LCA, Environmental Life Cycle Costing and Social Life Cycle Assessment are involved in order to be in a better position to further tackle (micro)plastic pollution. In addition, a mix of instruments should be considered and in parallel, there should be an aggressive campaign against the use of plastics at all levels of the society.

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Boodhoo K is the sole contributor to this review paper.

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# Tree Species Diversity Status and Contributors to Forest Degradation in Shasha Forest Reserve, Nigeria

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*Keywords: cropland; deforestation; forest degradation; forest management; ecological community; tree species diversity indices; shasha forest reserve.*

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# Tree Species Diversity Status and Contributors to Forest Degradation in Shasha Forest Reserve, Nigeria

Ogunrinola, Oluwaseun Femi [α], Ogunwale, Taiwo Olusegun [σ], Oyetola, Simeon Oyesoji [ρ] & Salami, Kaseem Dele [ω]

*Abstract-* Deforestation and forest degradation are related to human-induced activities practiced compared to the conservation of forests and their management in Nigeria. This work evaluated the diversity status of tree species in Shasha Forest Reserve utilizing a simple random sampling method for plot differentiation, with a transect established in the assessment area. Sixteen sample plots of 25 m x 25 m were found within the minimally protected and unprotected plots of the reserve. Descriptive statistics were used to analyze the data generated. The results of the tree appraisal showed that 644 individual trees and 60 different tree species (23 families) were identified. The tree species diversity indices obtained were (3.855 and 0.596) for Shannon-Weiner and species evenness, respectively. Rauvolfiavomitoria of the family Apocynaceae (46) was the most predominant tree species, followed by Celtiszenkeriof, the family Ulmaceae (32), and the families with the highest number of species were Sterculiaceae (8) and Euphorbiaceae (7). The encroachment into the forested area is increasing and signifies leading contributors to deforestation and forest depletion in this ecozone. Despite the large spacing in the Shasha forest reserve, woody plants remain moderately varied in composition, and it has a great potential for restoration if suitably managed with silvicultural interferences like seed supplementation and, or enrichment planting, which would promote the rapid return of the intricate forest status.

*Keywords: cropland; deforestation; forest degradation; forest management; ecological community; tree species diversity indices; shasha forest reserve.*

## I. Introduction

Deforestation and forest degradation are associated with human activities working against the protection of forests and their management in Nigeria. Knowing the factors leading to deforestation and forest degradation, twin problems influencing sustainable forest management, and on-site biological diversity conservation will assist in implementing policies to control them. These twin human activities are closely related to socio-political, economic, and demographic problems. About 10 million hectares of rainforests are destroyed yearly (FAO, 2015), and based onthe report by Ogunrinola et al. (2020) the species-rich tropical rainforests in Nigeria have been under severe stress to meet needs for forests and non-forest products, leading to painful destruction concerning bizarre and bulk of the wooded area habitat.

A document by FAO (2015) revealed that Nigeria has one of the universe's most significant amounts of primary forest deforestation. It lost 55.7 percent of its primary forests between 2000 and 2005 (Butler, 2005). A scenario that Wilcox (1995) examined to encourage habitat fragmentation generally results in species extinction, adecline in species diversity, and a reduction in primary productivity. Knowing the contributory factors and fundamental impact of deforestation and forest degradation is needed to design trade-off policies for their causes. Forestry Management Evaluation and Coordinating Unit (FORMECU, 1999) noted that about 58 (10.4%) of 560 tree species in Nigeria's forest are endangered. The investigations carried out in Queen's Forest, Oluwa Forest, and Elephant Forest by Onyekwelu et al. (2008) revealed that 16 of 51species, 15 of 45 species, and 8 of 31 species, respectively were endangered. Onyekwelu and Fuwape (2008) believed that not more than 5% of Nigeria's tropical wood is left without severe degradation.

Alarmingly in Nigeria, the primary contributor to deforestation and habitat fragmentation are crop production, fuel, and building supplies. In the northern part of the nation, excessive grazing, and clearance of trees for fuelwood for cooking arealso major issues. In the southwest of the country, logging (commonly in size) continues to cause the growing fragmentation of remnant forestry ecozones. General essential infrastructural development (roads, power lines, mining, built-up areas, and the likes) are primary factors. These factors are aggravated by outdated forest laws and weak law enforcement, a lack of training and capacity in

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the forestry industry, and a general shortage of resources for forest management at all tiers (federal, state, and local government). It is significant to point out that Nigeria is the Federal Republic with a high level of self-reliance at the state tier. While the Federal Ministry of Environment sets national policies, it has little enforcement power.

Enforcement of forest management relies on each nation's 36 states, each of which has its forestry laws guided by those at the federal level. In several states, the management power of the state forestry departments and indigenous organizations is poor, with low funding, low staff morale, inadequate technical training, illiteracy from citizens and decision-makers, shortage of logical forest policies (lacking in most of the nation's development plans), distortion due to oil economy and usually high rates of government corruption.

In Osun State, agricultural expansion and commercial tree felling remarkably rank on the list of deforestation contributors, while urbanization and domestic energy use come next. As with other states, poor conservation and poor implementation of forest laws, policies, and regulations intensify these deforestation contributors. Previous research done by Ogunrinola et al. (2020) highlighted that the major contributors to deforestation and habitat fragmentation in Nigeria were owing to land clearing for arable land, plantation establishment, unrestrained exploitation, population settlements, excessive grazing, charcoal business, poaching, construction, and poor funding of the forestry subsector. To Morales-Barqueroet al. (2015), the intensity of forest degradation is linked to landowners' decisions managing their shifting farming practices.

There is a growing concern in determining ecosystem qualities like forest structure, floristic composition, and species richness in primary forests (Ogunrinola et al., 2020). This arises from the government's concernin reinstating the nation's severely degraded primary forest ecological community. A situation that has guaranteed theadoption and execution of sustainable forest management practices like REDD+ (Reducing Emissions from Deforestation and Forest Degradation) in some parts of the country. Knowing the multitudes of factors fostering deforestation and forest loss in the forestland reserves will assist in applying REDD+ policies that will control this social milieu and encourage forest ecosystem sustainability (Oladipo et al., 2001).

Increasing food production is the number one major contributor to deforestation emissions universally and especially in Nigeria, where the level of deforestation is put at 3.5% per annum as revealed by the Environmental Management Programme Survey (Federal Ministry of Environment, 1999). The evaluation of vegetation and land management variation between 1978/78 and 1993/95 authorized by the Federal Department of Forestry reported that there was substantial expansion in the expanses of agriculture as all kinds of agriculture recognized developed by a total of 84,073km2 within the 18 years (FORMECU,1999).

Likewise, grazing land seems to be increasing irrepressibly. Its area enlarged from 18.3 percent in 1976/78 to 20.06 percent in 1993/95 (FORMECU,1999). A speedily rising population employing a finite resource lacking changes in land use designs or technological developmentsincreases the pressure on land with related destruction hence this study.

The paramount significance of the paper was to add initial information on the subject of study. Therefore, it was bound that this study would add to the available literature on the subject. Results from this study will be useful in the following aspects: (i) identify and analyze tree species diversity and richness under different physiognomy, (ii) identify and analyze tree biodiversity abundance under different physiognomy, and (iii) study seasonal differences in tree biodiversity abundance under each physiognomy.

Similar literature on the above topic have been studied(Adedeji and Adeofun, 2014; Awotoye et al., 2013). The subsequent gaps (which this current work attempts to fulfill) were discovered. There are documented studies on deforestation and forest depletion, most of which occur in Nigeria, but there are just a couple that emphasize on evaluation of deforestation and forest loss in Shasha Forest Reserve (Adedeji and Adeofun, 2014; Awotoye et al., 2013). This manuscript attempts to highlights the status of tree species diversity degradation in Shasha Forest Reserve with a focus on the state of deforestation and habitat fragmentation. Furthermore, the gaps in the attribute of the site of the study need to be checked. A diversity of the literature studied was conducted in the Southwestern region, and none, focused on the deforestation and forest loss quality condition of Shasha Forest Reserve. This study was a comprehensive study on the tree species diversity and richness under the different physiognomy ofthe forest reserve ecosystem.

This work aims at expanding insight into the interaction between deforestation and degradation, in a bid to identify the factors responsible for tree species diversity degradation in the study region.The aim of this research is also to apply geospatial techniques together with field evaluation of tree diversity state to identify the factors and status of tree species diversity degradation in Shasha Forest Reserve, Southwestern Nigeria.

## II. Materials and Methods

### a) *Site Depiction and Experimental Design*

This study was conducted in Shasha Forest Reserve in Osun State, Southwestern Nigeria. The study

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site situates on latitude and longitude (7º 05′ and 4º 55′ E) at an altitude of 178 m above water level. The forest reserve is located within the rainforest ecozone with a land cover of 337.298 km2 (Field Trip Earth, 2008). It has experienced a quick degradation from poaching and indiscriminate timber harvesting, wildfires, fuelwood gatherers, and transformation to plantations and cropland (Field Trip Earth, 2008). It has a mean annual rainfall of 1421 mm (Adekunle, 2006), most of which falls during the rainy season from April to October. Shasha Forest Reserve was chosen for the studies because its long-term land-use history is known. The extensive forestland is named after the "Shasha River", a large river in the study area. The Shasha River lies within the 337.298 hectares of land, which comprise the forest reserve. It has mixed moist vegetation. This reserve is one of the few forests that comprise some ecologically distinctive flora and fauna in South western, Nigeria and also includes different forest physiognomies of concern such as indigenous natural forest, non native tree plantation, and arable lands, respectively. The sampling was carried out for a period of twenty-four months (January 2020 to December 2021), spanning two wet seasons and two dry seasons. The variation in the explanatory parameters was utilized in evaluating the physiognomies that were most appropriate for species diversity conservation.

*b) Sampling Technique for Tree Species Evaluation*

A simple random sampling technique was adopted for the reasonably protected and unprotected plot. A sample plot of 100 m × 100 m area was marked.

The 100 m × 100 m area was demarked within the field. The sampling units 25 m × 25 m were located where the vegetation was relatively protected, and the edge effect satisfactorily surmounts. Sixteen fields were chosen in the tracts for the study, eight each at the two end corners of each lot. Tree species within diameter at breast height (dbh) > 10 cm were classified, and assigned to families, and relative diversity (the number of species in a family) was determined. Most plants were classified on the field, but plants that could not be classified were tagged "unidentified", and portions of that woody species (leaves, bark, and fruits) were taken to the Forestry Herbarium, Ibadan (FHI) of Forestry Research Institute of Nigeria for classification and identification. Each tree species was recorded separately in the field forms, and a possible attempt was identified not to neglect any qualified stem in a sample plot. After the floristic survey of the sampled sites, the tree will be classified into species and families, species richness and abundance of each species in the biotic community, and will be established applying the Shannon-Weiner index specified by Ogunrinola et al. (2020). The number of trees found in the sampling plots on a species basis was estimated by multiplying it by the number of parcels ha–1 to see the abundance of the species in one hectare.

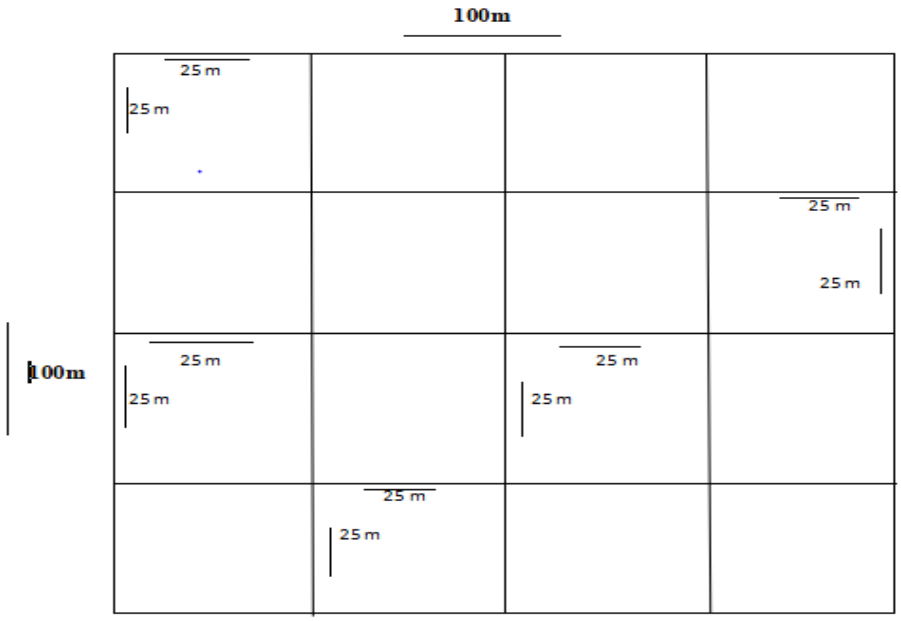


*Figure 1:* Plot Layout with Simple Random Sampling Technique



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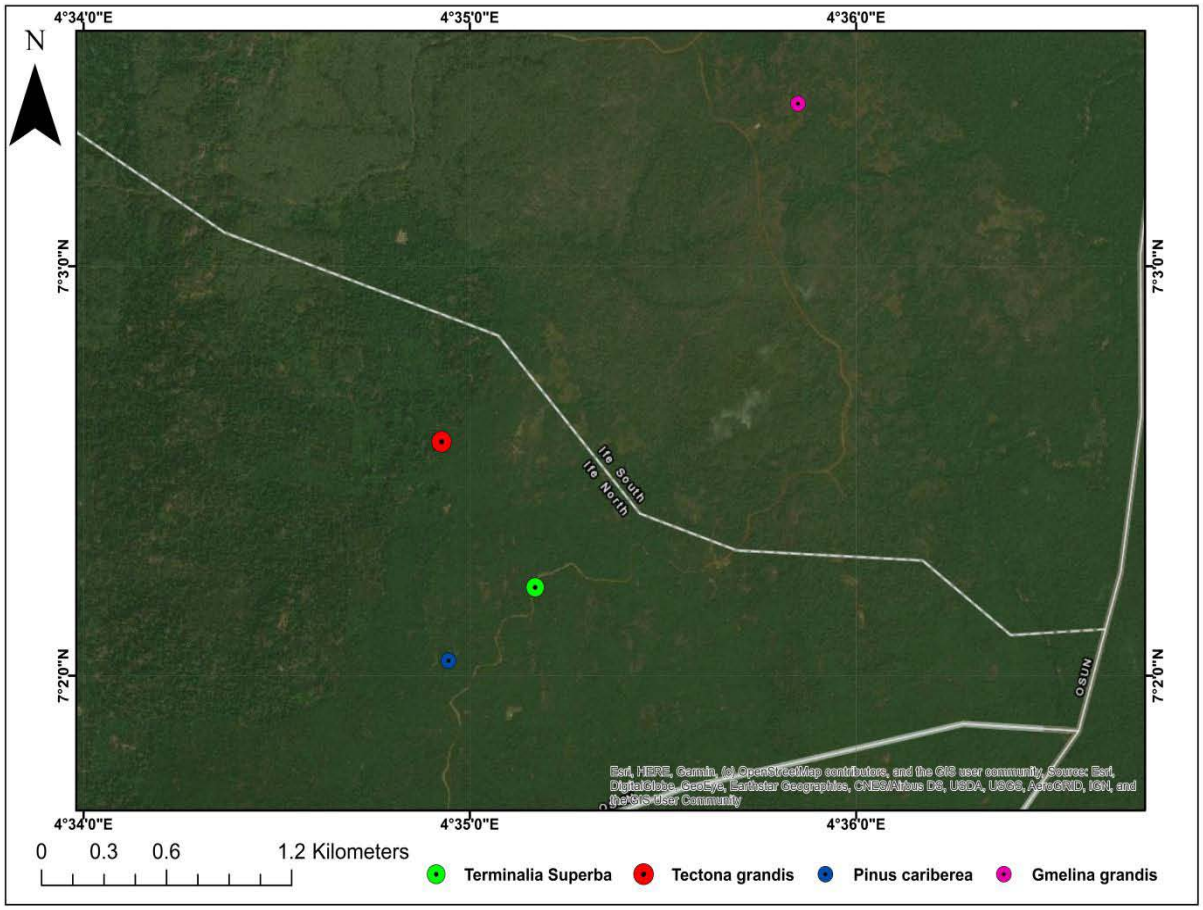


*Figure 2:* Map of the Study Area

c) *Plant Species Identification, Grouping, and Biodiversity Indices*

Plant species composition, abundance, and the number of families were established for each plot in line with their countenance. A marker was employed to label each enumerated woody plant to prevent double enumeration. The biodiversity indices were found for each sampled point and were used for the comparison of species diversity among the physiognomies.

The subsequent biodiversity indices were found for the location

- Species Relative Density (RD) number of individuals per hectare was found by applyingthe formula in line with Ogunrinola et al. (2020):

$$RD = \left[\frac{n_1}{N}\right] \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots eqn \quad (1)$$

Where RD = relative density, ni = the number of individuals of species i, and N = the total number of individuals in the whole population.

- Species Diversity Index was extrapolated by applying the Shannon-Weiner diversity index (Ogunrinola et al., 2020):

$$\sum_{i=1}^{s} p_i \ln(p_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots eqn \quad (2)$$

*Where:*

H' = Shannon-Weiner diversity index
S = Total number of species in the community
Pi = Rate of S constituted of the ith species
ln = Common logarithm

- Species Evenness in each community was carried out by applying Shannon's equitability (EH):

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$$E_H = \frac{H^i}{lnS^i} = \frac{\sum_{i=1}^{s} P_i \ln(P_i)}{\ln(S)} \ldots\ldots\ldots\ldots\ldots eqn \quad (3)$$

## III. Data Analyses

The data collected were subjected to appropriate descriptive analysis for tree species diversity and richness and the abundance under the different physiognomy, and subjected to analysis of variance (ANOVA).

## IV. Results

The results of the tree relative density showed that 9 (39.91%) of the local tree species observed were the predominant onespresent during the study (Table 1). Six hundred and forty-four (644) individual tree stands, belonging to 60 species and 24 families of the trees were recorded. Rauvolfia vomitoria of the family Apocynaceae (46) mainly predominated tree species, followed by Celtiszenkeriof the family Ulmaceae (32), and the families with the highest number of species were Sterculiaceae (8), Euphorbiaceae (7), and Ebenaceae (6) (Table 1). The tree species diversity indices obtained showed that Shannon-Weiner diversity and species evenness were (3.855and 0.596), respectively. Rauvolfia vomitoria of Apocynaceae family had the highest Shannon–Weiner (0.189, 0.029) and Diospyrosmon buttensis, Diospyros canaluculata of Ebenaceae family, Memecylon afzeliiof Melastomataceae family, and Oxyanthus specious of Rubiaceae had the lowest Shannon–Weiner respectively (0.010, 0.002).

*Table 1:* Family Distribution of Genera, and Species in Shasha Forest Reserve in both Seasons

| Family Name | Species Names | No of Genera | No of Species | Total No of Species |
|---|---|---|---|---|
| Annonaceae | *Clestopholis patens* (Benth.) Engl. and Diels | 1 | 1 | 6 |
| | *Enantiachlorantha* Oliv. | 1 | 1 | 3 |
| | *Xylopiaaethipica*(Dunal) A.Rich | 1 | 1 | 3 |
| Apocynaceae | *Alstonia boonei* DeWild. | 1 | 1 | 10 |
| | *Funtumiaelastica*(Preuss) stapf | 1 | 1 | 19 |
| | *Holarrhena floribunda* (G.Don) T. Durang&Schinz | 1 | 1 | 5 |
| | *Pricalima nitida* (Stapf) T Durand &H.Durand | 1 | 1 | 30 |
| | *Rauvolfia vomitoria* Afzel. | 1 | 1 | 46 |
| Bignoniaceae | *Mikhamia*sp | 1 | 1 | 7 |
| | *Spathodeacampanulata* P. Beauv. | 1 | 1 | 13 |
| Caesalpiniodeae | *Danieliogea*(Harms) Rolfe ex Holland | 1 | 1 | 10 |
| Capparaceae | *Buchholziacoriacea* Engl. | 1 | 1 | 18 |
| Combretaceae | *Terminalia ivorensis* Chev. | 1 | 2 | 21 |
| | *Terminalia superb* Engl. & Diels (Limba) | | | |
| Ebenaceae | *Diospyrosbarterii* Hiern | 1 | 6 | 78 |
| | *Diospyros canaluculata* De Wild | | | |
| | *Diospyrosdendo* Welw.exHiern | | | |
| | Diospyrosmonbuttensis Gurke | | | |
| | *Diospyrossuaveolens*Gurke | | | |
| | *Diospyroscanaliculata* De Wild | | | |
| Euphorbiaceae | *Drypeteschevellerii* Beille | 1 | 4 | 40 |
| | *Drypetes floribunda* (Muell.Arg) Hutch. | | | |
| | *Drypetespaxii*Hutch. | | | |
| | *Drypetesprincipum* (Muell.Arg) Hutch | | | |
| | *Macaranga barteri* Mūll-Arg | 1 | 1 | 19 |
| | *Ricinodendronafricanum*(Ball.) Pierre | 1 | 2 | 5 |
| | *Ricinodendronheudelotii*(Ball.) Pierre | | | |
| Malvaceae | *Nesogordoniapapaverifera*(A.Chev.) R.Capuron | 1 | 1 | 6 |
| Melastomatacae | *Memecylon afzelii* G.Don | 1 | 1 | 1 |
| Meliaceae | *Entandrophragmaangolense*(welw.) C. DC | 1 | 1 | 5 |
| | *Guareacedrata*(A.Chev.) pellegrin | 1 | 1 | 5 |



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| | | | | |
|---|---|---|---|---|
| | *Trichlisiamonadelpha* A Juss | 1 | 1 | 19 |
| Moraceae | *Ficus exasperate* Vahl | 1 | 1 | 12 |
| | *Milica excelsa* (Welw.) C.Berg | 1 | 1 | 8 |
| | *Morusmesozygia* Stapf | 1 | 1 | 4 |
| | *Musangacercropioides* R.Br | 1 | 1 | 26 |
| | *Myrianthusarboreus* P. Beauv. | 1 | 1 | 4 |
| Myristicaceae | *Pycnanthusangolensis* (Welw.) Ward | 1 | 1 | 11 |
| Olacaceae | *Strombosiapustulata* Oliv. | 1 | 1 | 26 |
| Pandaceae | *Microdesmispuberula* Hook f. ex planch | 1 | 1 | 13 |
| Passifloraceae | *Barteriafistulosa* Mast | 1 | 1 | 3 |
| Rubiaceae | *Canthiumhispidium* Benth | 1 | 1 | 2 |
| | *Oxyanthus specious* DC | 1 | 1 | 1 |
| Sapindaceae | *Chytranthusma crobotry* (Benth) | 1 | 1 | 3 |
| Sapotaceae | *Aningeriarobusta*(A.Chev.) Aubrev. And Pellegr. | 1 | 1 | 12 |
| | *Malacthaalnifolia (*Baker*)* Pierre | 1 | 1 | 4 |
| Sterculiaceae | *Cola gigantean* A.Chev. | 1 | 1 | 20 |
| | *Hildegardia barteri* Schott &Endl | 1 | 1 | 2 |
| | *Mansonia altisima* A Chev. | 1 | 1 | 21 |
| | *Octolobuangustatus*Hutch. | 1 | 1 | 8 |
| | *Sterculiaoblonga* Mast | 1 | 3 | 36 |
| | *Sterculiarhinopetala*K. Schum. | | | |
| | *Sterculiatragacantha* K. Schum | | | |
| | *Triplichiton scleroxylon* K.Schum | 1 | 1 | 6 |
| Tiliaceae | *Desplatsiadewevrei* (De. Wild. andTh.Dur.) Burret | 1 | 2 | 11 |
| | *Desplatsialutea* Bocq | | | |
| Ulmaceae | *Celtismildbraedii* Engl | 1 | 3 | 39 |
| | *Celtistenufolia Nutt.* | | | |
| | *Celtiszenkeri*Engl | | | |
| Violaceae | *Rinoreadentata*(P. Beauv.) Kuntze | 1 | 1 | 3 |

*Source: Field Survey,(2021)*

*Table 2:* Floristic Composition and Significance of Tree Species Recorded

| Family Name | Species Names | Common Name | Uses |
|---|---|---|---|
| Apocynaceae | *Alstonia boonei*De Wild. | Stool wood, pattern wood | Timber; Root and bark are used in the treatment of diseases. |
| Sapotaceae | *Aningeriarobusta*(A.Chev.) Aubrev. And Pellegr. | *Aningeria* | Veneer, carpentry, furniture, and interior joinery. |
| Passifloraceae | *Barteriafistulosa* Mast | Ant tree | Stem bark, roots, and leaves are used in disease treatment. |
| Capparaceae | *Buchholziacoriacea* Engl. | Wonderful kola | House construction; Fruits and seedsare consumed most time. |
| Rubiaceae | *Canthiumhispidium* Benth | Buje | |
| Ulmaceae | *Celtismildbraedii* Engl | Red-fruited stinkwood | Light construction, flooring, interior, furniture, and good for fuel. |
| Ulmaceae | *Celtistenufolia Nutt.* | Dwarf hackberry | Timber and fiber-rich bark are utilized for the manufacture of ropes and paper. |
| Ulmaceae | *Celtiszenkeri*Engl | Ivory coast | Light construction, flooring, interior, furniture, particleboard. |
| Sapindaceae | *Cyrtanthusmacrobotrys* (Benth) | savannah | |
| Annonaceae | *Cleistopholis patens* (Benth.) Engl. and Diels | Salt and oil tree | Timber and medicinal purpose |
| Sterculiaceae | *Cola gigantean* A.Chev. | Giant cola | Furniture; Nuts used in the manufacture of cola drinks. |

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| | | | |
|---|---|---|---|
| Caesalpinioideae | *Danieliaogea*(Harms) Rolfe ex Holland | West African gum | Plywood, joinery, general millwork, furniture, boxes, and decorative veneer. |
| Tiliaceae | *Desplatsiadewevrei* (De. Wild. And Th.Dur.) Burret | | |
| Tiliaceae | *Desplatsialutea*Bocq | | |
| Ebenaceae | *Diospyrosbarterii*Hiern | | The wood is used locally, and stems are used as chew sticks. |
| Ebenaceae | *Diospyroscanaluculata* De Wild | | |
| Ebenaceae | *Diospyrosdendo* Welw.exHiern | | |
| Ebenaceae | Diospyrosmon buttensis Gurke | | |
| Ebenaceae | *Diospyrossuaveolens* Gurke | | |
| Ebenaceae | *Diospyroscanaliculata* De Wild | | |
| Euphorbiaceae | *Drypeteschevellerii* Beille | | |
| Euphorbiaceae | *Drypetes floribunda* (Muell.Arg) Hutch. | | |
| Euphorbiaceae | *Drypetespaxii* Hutch. | | |
| Euphorbiaceae | *Drypetesprincipum* (Muell.Arg) Hutch | | |
| Annonaceae | *Enantiachlorantha*Oliv. | | |
| Meliaceae | *Entandrophragmaangolense* (welw.) C. DC | Tiama Mahogany English mountain mahogany | Timber, cabinetwork, exterior and interior joinery, veneer and plywood, shipbuilding. |
| Moraceae | *Ficus exasperate* Vahl | Forest sandpaper | Used for making canoes, house posts, furniture, stools, utensils, containers, and drums. |
| Apocynaceae | *Funtumiaelastica*(Preuss) stapf | West Africa rubber tree | Used for carving spoons, bowls, and other household utensils; Timber for beams and rafters in buildings[ |
| Meliaceae | *Guareacedrata*(A.Chev.) pellegrin | Scented guarea | The wood is used for house building, flooring, joinery, interior trim, paneling, window frames, doors, shipbuilding, vehicle bodies, furniture, cabinetwork, decorative boxes, crates, veneer and plywood. It is suitable for musical instruments. |
| Sterculiaceae | *Hildegardia barteri* Schott &Endl | | It is used to make ropes, floats, plates, and dishes. |
| Apocynaceae | *Holarrhena floribunda* (G.Don) T. Durang & Schinz | False rubber tree | It can be used as a glue;<br>used traditionally for carvings, combs, spoons, stirrers for the rice-pot, and handles for axes and small implements. |
| Euphorbiaceae | *Macaranga barteri* Mūll-Arg | | It is used as vermifuge and febrifuge. (antioxidant) It is also used to relieve cough and bronchitis |
| Sapotaceae | *Malacthaalnifolia (*Baker) Pierre | Country mallow | |
| Sterculiaceae | *Mansonia altisima*A Chev. | African black walnut | Used as high-class joinery, cabinetwork, furniture, turnery, decorative veneer and handicrafts.<br>It is also used in the construction of doors and windows, shop fittings, and boxes and crates |
| Melastomataceae | *Memecylon afzelii* G.Don | Edwinani | |
| Pandanaceae | *Microdesmispuberula* Hook f. ex planch | Diola | The twigs serve as chew stick;<br>It is used to make chairs, spring traps, |



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|---|---|---|---|
| | | | handles, and implements and made into a type of guitar. |
| Bignoniaceae | *Mikhamia spp* | | |
| Moraceae | *Milicia excelsa* (Welw.) C.Berg | African teak | It is used for construction work, shipbuilding and marine carpentry, sleepers, framework, trucks, draining boards, outdoor and indoor joinery, stairs, doors, frames, garden furniture, cabinetwork, paneling, flooring and profile boards for decorative and structural uses. It is also used for carving, domestic utensils, musical instruments, and toys. |
| Moraceae | *Morusmesozygia* Stapf | | The wood is suitable for sliced veneer, high-class furniture, flooring, staircases, joinery, and turnery, agricultural implements, toys, novelties, carvings, boxes, crates, vats, posts, poles, piles, mine props and shingles. |
| Moraceae | *Musangacercropioides* R.Br | Corkwood | Production of stools, musical instruments,walkingsticks, trays, baskets, toy popguns. |
| Moraceae | *Myrianthusar boreus* P. Beauv. | Giant yellow mulberry, Monkeyfruit | It is used to make domestic utensils and also used for fencing. |
| Malvaceae | *Nesogordonia papaverifera*(A.Chev.) R.Capuron | Red wood | It is used for general construction, floors, joinery, turnery, boatbuilding, tool handles, gunstocks, plywood, utility crossarms, and furniture. |
| Sterculiaceae | *Octolobusangustatus* Hutch. | | The stems are made into spear shafts |
| Rubiaceae | *Oxyanthus speciosus* DC | Whipstick loquat | The wood is used for building poles, whipsticks, and tool handle. The wood is used for fuel. |
| Apocynaceae | *Picralima nitida* (Stapf) T Durand &H.Durand | | Small dippers and spoons are made from the shell of the fruit. It is used traditionally to make items such as combs incense holders, spoons, walkingsticks, arrows, weaver's shuttle. |
| Myristicaceae | *Pycnanthusangolensis*(Welw. ) Ward | African nutmeg/ilomba | It is used for veneer peeling, panels, furniture frames, box-making, pencils, and minor joinery. |
| Apocynaceae | *Rauvolfia vomitoria*Afzel. | Poison devils pepper | Hunting poison |
| Euphorbiaceae | *Ricinodendronafricanum* (Ball.) Pierre | | It is used in making small kitchen utensils, carved material, dye, and tanning. |
| Euphorbiaceae | *Ricinodendronheudelotii* (Ball.) Pierre | African oil-nut tree | Paper pulp, bowls, used for fishnet floats and rafts for heavy timbers, used for rough planks and coffins. |
| Violaceae | *Rinoreadentata*(P. Beauv.) Kuntze | Oloborobo | Chewing stick |
| Bignoniaceae | *Spathodeacampanulata* P. Beauv. | African tulip tree | It is used for making blacksmiths' bellows. The wood is used for the carving and production of plywood. |
| Sterculiaceae | *Sterculiaoblonga* Mast | Yellow sterculia | It is used for flooring, beams, planks, and furniture. |
| Sterculiaceae | *Sterculiarhinopetala* K. Schum. | Aye | Timber, construction, flooring, joinery, interior trim, paneling, stairs, high-quality furniture, ship and boat building, turnery, tool handles, toys, poles, veneer and plywood. |



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| | | | |
|---|---|---|---|
| Sterculiaceae | *Sterculiatragacantha* K Schum | English African Tragacantha | It is used for posts, boards, and construction work. |
| Olacaceae | *Strombosiapustulata* Oliv. | Itako | Veneer, building poles and transmission poles, and heavy-duty flooring. |
| Combretaceae | *Terminalia ivorensis* Chev. | Idigbo/Ivory coast almond | Light construction, door and window frames, joinery, furniture, cabinetwork, veneer and plywood. It is suitable for flooring, interior trim, vehicle bodies, sporting goods, boxes, crates, matches, turnery, hardboard, particleboard, and pulpwood. It is used locally as planks, roof shingles, fencing posts, dug-out canoes, drums, and mortar. |
| Combretaceae | *Terminalia superba*Engl. & Diels (Limba) | Afara/ black limba | It is used as interior joinery, doorposts and panels, mouldings, furniture, officefittings, crates, matches, and especially for veneer and plywood. |
| Meliaceae | *Trichliliamonadelpha*A Juss | | The wood is used in house building, suitable for light flooring, joinery, interior trim, shipbuilding, vehicle bodies, furniture, cabinetwork, boxes, crates, toys, novelties, veneer, particleboard,plywood, hardboard and as well as pulpwood for paper production. |
| Sterculiaceae | *Triplichiton scleroxylon* K.Schum | Obeche | Timber and woodwork |
| Annonaceae | *Xylopiaaethipica*(Dunal) A.Rich | Ethiopian Pepper | It is used for making bows and crossbows for hunters and warriors. It is used also for requiring resilience such as boatconstruction, masts, oars, paddles and spars |

*Source: Field Survey,(2021)*

## V. Discussion

A designed evaluation for an exploratory, checklist of biodiversity species, genus, and their families in biological Shasha Forest Reserve, Osun State,was revealed in Table 1. A total of six hundred and forty-four (644) species distributed into forty-five (45) genera were identified in Shasha Forest Reserve. Rauvolfia vomitoria of the family Apocynaceae (46) mainlypredominated tree species, followed by Celtiszenkeriof the family Ulmaceae (32), and the families with the highest number of species were Sterculiaceae (8), Euphorbiaceae (7) and Ebenaceae (6) (Table 1). From the study that was conducted in the sampling site, it was observed that Rauvolfia vomitoria (Apocynaceae) had a moreprevalent dominant species in the whole four sampled plots because the species is more suitable for the geographical area in terms of survival rate and reproduced more frequency by natural means (through the dispersal of seedlings by wind, water, birds and rodents, and biological agents) which causes it to be in more abundances than the other tree species.

The results also revealed that a substantial part of Shasha Forest Reserve had been altered between 1986-2021. Most of the forested areas have been encroached on by farmers for crop production and the like purposes. This result corroborates the study of Nathaniel et al. (2012), which revealed a steady decline in forest and land utilization intensification with expansion in croplands/fallow ground and housing areas in south western Nigeria. The notice able fallin forested ranges and rise in the arable land was not without a heavy toll on the tree species.

The number of tree species (60) found in the study area is lesser relative to the number found by Ihenyen et al. (2010) in Ehor Forest Reserve, Nigeria.

The result was equally lower comparative to the report of several scholars in other tropical forests (Gerald et al., 2004).The decline in forested habitats and tree species compared to earlier studies in the tropical wood could be due to increasing human intrusion into the forest reserve in need for agricultural purposes by farmers who currently settled in villages that have now been opened within the forest and fringes and borders.

The expansion in cropland and reduction in the forest range confirms the claim of Adedeji and Adeofun (2014) that forests were cleared to make way for food and tree crops. The number of tree species per hectare



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(60) recorded in this study was observed to be higher than the number of species recorded (55) in the same area by Adekunle (2006) and (Onyekwelu et al., 2005).

Part of the explanation for this may be that moderatelyor slightly unprotected tropical forests are likely to maintain more plant speciesthan a forest that is dense and protected (Mishra et al., 2004). This also shows the degree to which man has encroached on theforest between 2000 and 2021. The more varied a range is, and the, more its unchangeability. The overall Shannon's equitability of 0.596 for this study is smaller than the 0.66 observed by Onyekwelu et al. (2005) for Queen Forest, an unaltered ecological community reserve in Ondo State. This showed lower naturally-occurring of individual tree species within the species reported, indicating that species evenness lesser declined as forest depletion intensified. This agrees with the finding of Nath et al. (2005) for tropical biomes in India that tree species'evenness declined with the rise in intensity of forest stress. The results of the tree relative density showed that 9 (39.91%) of the indigenous tree species observed were the predominant onespresent during the study (Table 1). Shasha Forest Reserve, generally is predominated by tree species in the families Sterculiaceae, Euphorbiaceae, and Ebenaceae.This result is corroborated by Adekunle (2006), who observed Sterculiaceae; Euphorbiaceae, has one of the prevalent families in the primary forest of the research area. Furthermore, Ihenyen et al. (2010) in Ehor Forest Reserve in Edo State also observed that Sterculiaceae, Euphorbiaceae, and Ebenaceae be among the predominant families in those forest reserves.

The types of tree species such as (Pricalina nitida, Celtiszenkeri, Diospyrosspp, Strombosiapustu lata, and Sterculiarhinopetala.) primarily found in this range are immature for commercial timber uses, because most of them are below the merchantable girth of (48 cm) required for harvesting. This signifies that the ecological community has been previously logged, during which matured invaluable economic trees have been selectively exploited. Strombosiapustulata Oliv was one of the predominant tree species found by Adekunle (2006) in the primary forest of the study area 2006.

Nevertheless, some of these tree species Strombosiapustulata Oliv, Diospyros spp, and Funtumiaelastica (Preuss) Stafp, were among the tree species obtained by Onyekwelu et al. (2008) to dominate Oluwa Forest Reserve, the adjacent forest reserve to the study area.

Therefore, considerable numbers of the tree species found are fewer in abundance due toexploitation and degradation of the forest area and rate of conversion to cropland.

This study was designed to assess the woody plant diversity to signify the number and variety of diverse species in the ecosystem within the area under investigation. Good insight on how to give proper accountability of a reserve and to preservediversity is crucial for both current and subsequent generations.

The structural composition of tree species conservation within Shasha Forest Reserve is fast declining owing to the encroachment of arable farmlands into the forested area. The increasing of cultivated farmlands and non-forested, abandoned sites, uncontrolled logging, charcoal business, comercial fire collection, human population settlement, and habitat fragmentation are severe degrading factors within the reserve. In reversing this, urgent measures have to be taken to give a trade-off for land needed for subsistence agriculture and impaired land meant for afforestation in place of primary forest in Shasha Forest Reserve. Management interferences like enrichment planting, regulated selective logging, and protection of biological regeneration can further aid in restoring this ecological community. Finally, planned of regenerating the indigenous tree species in the forest reserve is an imperative means to confront the present rate of depletion in the area. Further study on the factors contributing tothe such menace is recommended to monitor the seasonal variations in contents of biodiversity indices and relate to the past treespecies diversity studies. The work has provided information on the extent of forest degradation in the Shasha Forest Reserve as a way of evaluating the ecological health of the study field as a result of deforestation. The work also added to the benchmark information on plant species diversity indicesstudiesin our environment.

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*Statement of Competing Interests*

The authors declare that they have no competing interests.

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# Overview of the Geothermal Sources in Kyrgyzstan

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*Abstract-* At the present energy independence along with global warming for high mountain regions is quite significant issues. Impact of climate change on water resources, which accompanied by melting glaciers and snow cover, leads water shortage. About 94% generated energy in Kyrgyzstan produced from water resources. Shortage of water resources created for society in sustainable development of economy and challenge of severely ecological consequences. Therefore, one of the adaptation measures to the climate change is looking for alternative way with usage of renewable energy. For ensuring of energy safety of the population of Kyrgyzstan as a priority should be taking account usage of solar, biomass and geothermal energy.

Aim of this work is study of qualitative composition of geothermal resources of Kyrgyzstan in case study of Issyk-Kul province. Geothermal resources are mainly concentrating in recreation zones of Issyk-Kul province and have a low-temperature characteristic.

*Keywords: geothermal sources, issyk-kul province, renewable energy, sustainable development of region, ecological and economic assessment.*

*GJSFR-H Classification: DDC Code: 621.042 LCC Code: TJ163.2*




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# Overview of the Geothermal Sources in Kyrgyzstan

N. Degembaeva [α], E. Baibagyshov [σ] & Ch. Kukanova [ρ]

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## I. Introduction

In world practice, geothermal energy finds its wide application in heating premises, resorts, hospitals, greenhouses, in general, in economic activity. In agricultural production, which is the main activity of this region, the use of thermal water will provide tangible benefits.Heating livestock complexes, heating drinking water for livestock in winter, the use of wastewater in fish breeding ponds is no less promising areas of geothermal heat utilization. The use of complex geothermal source schemes in the cold season allows you to supply hot water from the well in the heating system of greenhouses.The waste water through the system forms a temperature difference of 25 ° C. Then water with a temperature of about 50 ° C is sent to livestock farms. After circulation of such scheme, the water temperature is 25-30 ° C and goes for tanks and ponds.

During the warm season, using water from artesian wells to irrigate outdoor vegetables can increase yields by 25-30%.Geothermal water can be used in energy-intensive technological processes, such as heat treatment of concrete in construction, washing wool, drying wood and others.The thermal springs are especially important in the treatment of various diseases, their chemical composition has therapeutic properties.Another important aspect of using geothermal sources is the extraction of valuable chemical elements and various compounds from water: iodine, bromine, sodium chloride, boric acid, alkali, sulfur, Glauber's salt, etc. [1]. The economic value of these resources is significant.

Not only in the Issyk-Kul region, but also in other areas of the Republic, the use of renewable energy sources is not yet widespread. The study of the literature, gives the background to the need to introduce this type of energy sources, as with global climate change, the large demand for natural resources and a sharp increase in population cannot provide the necessary conditions and products from natural resources in a timely manner. The purpose of this work is to study the qualitative composition of geothermal sources of Kyrgyzstan, on the example of the Issyk-Kul region.

## II. Materials and Methods

### a) Subject of the Study

The Kyrgyz Republic is rich in natural resources, the Issyk-Kul region, located in the northeastern part of the Republic and is an administrative and special natural-climatic zone. In the north of the Issyk-Kul hollow is the Kungoi Ala-Too ridge, the southern border of the region is the Teskei Ala-Too ridge, which sharply separates it from the inner Tien Shan. The total length of the Issyk-Kul basin, including the slopes of the surrounding ridges, is more than 250 km with the greatest width of 100 km. The area of the region is 43.1 thousand square kilometers, which is 21.6% of the country's area [2]. The landscape of the Issyk-Kul hollow is quite complex and is represented by a complex of plains, foothills and mountains [3].

Number of residents 470.1 thousand people, number of inhabitants per 1 km$^2$ 11 people (2017 at the beginning of the year). The administrative-territorial structure of the Issyk-Kul region includes five districts, according to favorable agro-climatic conditions,

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specialized for growing grains, fodder crops, vegetables and fruits (total area of cultivated land is 87.1 thousand ha, i.e. 15.4% of the total area of cultivated land of the country), small and cattle and horse breeding. There are 3 cities, 2 urban-type settlements, 61 rural areas. The urban population is 128.9 thousand people, the rural population is 329.6 thousand people [2].

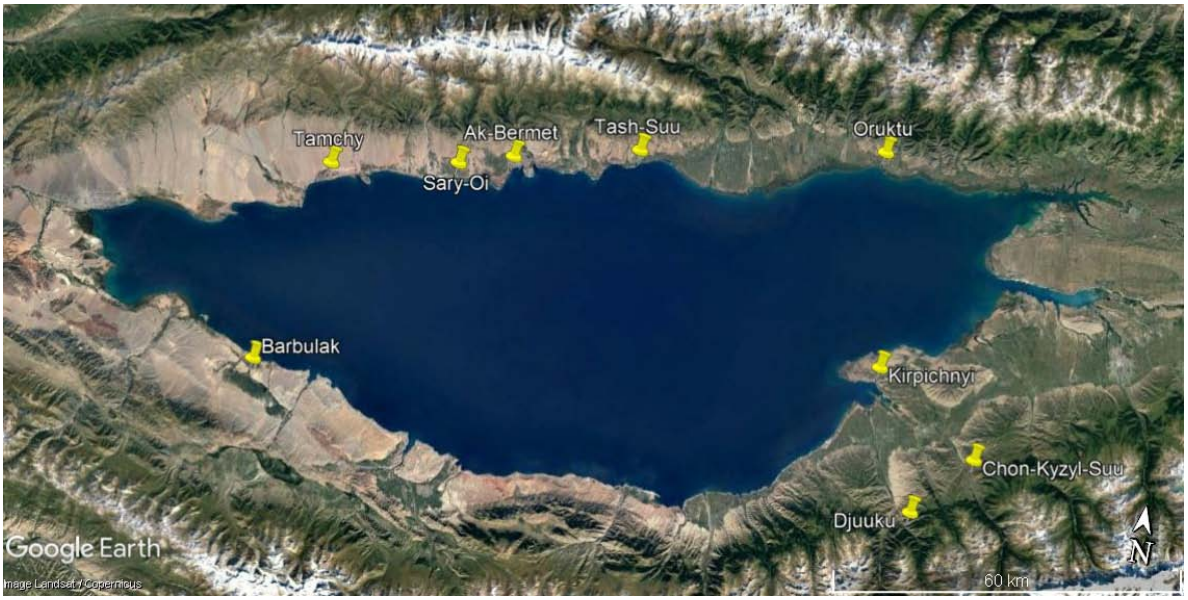


*Figure 1:* Location Map of Geothermal Sources in Issyk-Kul Region

## III. Methodology

The methodology of this study includes a review of the literature on the issues of relevant topics. As input data geothermal resources are used data on the mineralogical resources, the topography of the area in the form of its digital model. The variability of the climatic regime of the study area was studied using data from the meteorological stations of Cholpon-Ata city. The collection and systematization of hydrochemical data are compiled for the location of geothermal resources [4].

## IV. Results

This area contains a huge reserve of mineral and thermal waters, which can be applied as renewable energy resources. Jetty-Oguz resort is located on the northern slope of the Teskei Ala-Too ridge at a distance of 30 km from Karakol at an altitude of 2.200 m above sea level. The main characteristics of the resort waters are represented as medium-mineralized (11-13 g/l) and medium-mineralized (9-11g/l). Of these mediums mineralized (11-13g/l) thermal (39-40˚C) Rhodonium medium concentration (111-154 nCi/L) calcium-sodium chloride water well 1-K is used for balneotherapy. Low saline (9-11g/l) thermal (35-47˚C) slightly rhodonated (5.3-10.6nCi/l) calcium-sodium chloride waters of the well 6 are used for balneotherapy. Radon water from well 5 is mainly used for therapeutic and drinking purposes. These waters have a temperature of 23-25°C and a low concentration of calcium and sodium chloride (3-4 g/l) at an average concentration (45.0-54.0 nCi/L).

Zhyrgalan resort is located in the Issyk-Kul basin, 6 km from Karakol. The therapeutic base of this resort is slightly mineralized (0.9 g/l) thermal (35-43˚ C) waters of the well 1-A, discovered in 1960, as well as of the well 2/74, drilled in 1974. Mineral waters are characterized by sulfate-chloride sodium composition, alkaline reaction. The balneo-technical condition of the wells is in good condition. These thermal waters with the volume of 1728 $m^3$/day are recommended both in the balneotherapy for expansion of the spa area and industrial bottling

The Ak-Suu mineral water deposit is located in the southeast of the Issyk-Kul hollow, on the northern part of the Teskei Ala-Too ridge, in the narrow gorge of the river of the same name. The nearest settlement is the village of Teploklyuchenka, situated 5-6 km away. Ak-Suu thermal waters are similar to the Issyk-Ata thermal waters. The water flow rate of the three operating wells is 864.0 $m^3$/day, the water temperature is up to 58˚C.

The Barbulak deposit is located on the southern shore of Lake Issyk-Kul to the east of the town of Balykchy. Water salinity is 4.0-4.7 g/l and is characterized by sulfate-chloride calcium-sodium composition.

Cholpon-Ata thermal water deposits (35-53°C) are represented by medium and high-mineralized calcium-sodium chloride (15-40 g/l) springs. It is located in the northern part of the coastal strip of Lake Issyk-Kul. They are brought to the surface by a number of wells from 800-200m depth and found wide application



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in:Blue Issyk-Kul (wells 773.1/81), Cholpon-Ata (well 846), Issyk-Kul (wells 775, 1268), Kazakhstan (well 999), Ala-Too (well 887).

Kosh-Kol, wells 1112, 1112, -A, 1375 are located 30-39 km from Rybachie. Thermal (39-42° C) waters are brought out on the northern shore of the lake.The flow rate of the wells is 2592, 2281, and 1296 $m^3$/day, respectively, water salinity is 0.6-1.7 g/l and sodium chloride-sulfate and sulfate-chloride composition. The pH value is about 7.80 to 9.50. Silicic acid concentration is up to 40 mg/l and fluorine-12 mg/l.

Tamchi. Well 1579 was drilled in 1984 in the territory of Tamchyvillage. The water flow rate is 1347, 8 $m^3$/day. Water temperature is 42° C, pH 8.9, salinity 0.5 g/l, the composition is characterized by sodium chloride-sulfate, concentration of silicic acid 40 mg/l, fluoride 2.2 mg/l. Thermal water is used for household and domestic needs.

Chock-Tal, well 1517. Drilledin 1983 with a supply of 1036 $m^3$/day and used for balneological and therapeutic-drinking purposes according to indications. Water temperature is 45°C, the reaction is alkaline (pH 9.50). In terms of composition, it belongs to the hydro-carbonate-sulfate sodium with mineralization of 0.5 g/l. The content of silicic acid is about 50-53 g/l. and fluorine 3-4 mg/l.

Chon-Sary-Oy well 1543, discovered in 1981 and located on the territory of the Altyn-Kum resort. Preliminary reserve of this spring is 503.7 $m^3$/day, temperature 36°C, pH -8.90. Water is characterized by mineralization up to 0.8 g/l chloride-hydrocarbonate-sulfate composition. Silicic acid content is up to 35 mg/l and fluorine content is up to 5.0 mg/l. Well 1215 with a flow rate of 1209.6 $m^3$/day and temperature of 29° C has a similar composition and properties of water of well 1543.

Kurskoye wells 833, 1516. Well 833 was discovered as one of the first on the shore of Lake Issyk-Kul. It was drilled in the end of 1985 in the territory of the boarding house "Geologist".Wells 1516 and 833 are put into exploitation to provide household needs. Mineral water of these wells is characterized as slightly mineralized (0.9-1.9 g/l) of sodium chloride-sulfate composition and alkaline (pH 8.50-9.12).Concentration of silicic acid is in the range of 31-45mg/l, fluorine-4,2-6,6mg/l. Preliminary water reserves for well 833-388-388 $m^3$, and for well 1516-604.8 $m^3$/d.

Dolinkawells 888 and 1183 were opened in 1979 and 1981, of which well 888 is mothballed, and well 1183 is used for self-monitoring and for domestic needs. Approximate water reserves of the wells make respectively 259.2 $m^3$/day and 224.6 $m^3$/day.Water composition of these wells is the same type of sulfate-chloride sodium water with significant fluoride content (up to 9.0 mg/l) and silicic acid (up to 50 mg/l). Water temperature is within 48-49°C with salinity of 2.2-2.9 g/l and water reaction is alkaline (pH 8.20-8, 8.55).

Karabulunskoe thermal water deposit (39-50°C) is located on the peninsula of the same name in the southeastern part of the Issyk-Kul depression, 15 km northwest of the Kara-Suu village. Exploration of the field was carried out in 1975-1981. Reserves amount to 3154 $m^3$/day. Waters of this deposit have an alkaline reaction (pH 9.50-10.50), low mineralization in the range of 0.3-1.2 g/l, different anionic composition. These waters are characterized by a high content of silicic acid (up to 52 mg/l) and fluorine (7.6-9.3 mg/l).

Ak-Terek, well 851 was drilled in 1979 with an estimated supply of 1296 $m^3$/day. The water temperature of the well is 26-27°C, the pH value is 8.90.The composition of this source belongs to the sulfate-chloride-hydrocarbonate sodium with a total salt content of 0.3 g/l.

The Chon-Kyzyl-Suu springs, represented by three springs, are located on the northern slope of the Terskey Ala-Too ridge, in the gorge of the river of the same name, 19 km to the south of the Kyzyl-Suu village. The Chon-Kyzyl-Suu springs, represented by three springs, are located on the northern slope of the Terskey Ala-Too ridge, in the gorge of the river of the same name, 19 km to the south of the Kyzyl-Suu village. Of the three springs, two of them are captive pools with overhead wooden logs. The water of the springs is clear, clean, fresh to the taste of hydrogen sulfide. Water temperature is 32.4-43.0°C, water reaction is alkaline (pH 9.0-9.08). The total water flow rate of the springs is about 1.5 l/sec. Their chemical composition is low-mineralized (0.4-0.5 g/l) sodium chloride-sulfate with a significant content of silicic acid (over 50 mg/l) and fluoride up to 9.5 mg/l.

The Juukuchak spring is located in the river gorge of the same name, 15 km away from these springs is the village of Kyzyl-Suu. Kyzyl-Suu. The springs are used by the local population. The water of the springs is transparent, clean, fresh to the taste with a smell of hydrogen sulfide. Water temperature 32.0-35.0°C, alkaline water with pH 7.9-8.70, flow rate 1 l/sec. Water refers to nitric, slightly mineralized (0.3-0.4 g/l), chloride-sulfate sodium, with silicic acid 50mg/l and fluoride -7-9 mg/l.

The Altyn-Arashan springs are located on the northern side of the Teskei Ala-Too ridge and are divided into three groups of springs: northern, middle and southern. These springs are characterized by the same composition. The Altyn-Arashan northern springs are located on the northern slope of the Ak-Suu river, 20-23 km southwest of Karakol. The water temperature varies from 35.5 to 43.0° C with a flow rate of about 1 l/sec. All the springs are captive, used for therapeutic purposes and are difficult to access.

Altyn-Arashan middle springs are located upstream the Ak-Suu River southeast of Karakol and are hard to reach. Along 1000 m along the river valley 15 outlets of the springs were fixed with the total flow rate



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according to the measurements of 1952. 6.5 l/sec. The water in them is fresh, with a smell of hydrogen sulfide, the temperature varies from 17.5 to 51.5˚C. Some of the springs are dripped and used by the local population for medicinal purposes.In the Ak-Suu Gorge, such springs are about 10 km away, and in the future can be used for heating purposes for the year of Karakol.

The Altyn-Arashan South springs are located in the basin of the Chatyr-Tor River. There are five known outlets of the springs with water temperature 45-51.5˚C, the total flow rate is about 1 l/sec.The spring water is transparent, clean, fresh to the taste and is presented as nitrogen slightly mineralized (0.3-0.5 g/l), alkaline (pH 8.15-9.04), siliceous (50mg/l), chloride-hydrocarbonate sodium composition. Increased fluoride content (up to 21 mg/l) from this source, which makes it unsuitable for therapeutic and drinking purposes.

## V. Discussion

Heat reserves determine the climate of the Issyk-Kul region. According to studies of lake posts, from April to August the air temperature is higher than the lake water temperature and air heats the water, and from September to March it is lower and the water heats the air. Thus, the average annual air temperature is 3.5-5.5˚C below the water temperature. This contributes to the conditions: the exchange is cool in summer and warm in winter. The average multi-year annual heat budget of Lake Issyk-Kul is 41700 calories/cm$^2$. According to D. Hutchinson, except for Baikal and Michigan, it is not typical for other lakes to have an annual budget exceeding 50.000cal/cm$^2$. [5]. Duration of sunshine during the year on Lake Issyk-Kul (2880 hours) is 1.3 times higher than the same indicator for Yalta (2250 hours) [6]. These climate factors create additional favorable conditions for the use of renewable energy sources and reduce the cost.

Currently, the population of the Issyk-Kul region, mainly use electricity generated by hydropower (about 98%), other types of energy are not developed. The main energy resources are imported at market prices and their consumption increases year after year. At the same time, the economy of the Kyrgyz Republic cannot afford such a high level of consumption of energy resources because our economy is considered to be energy-intensive. Although electrification covers about 99% of the population in the Kyrgyz Republic, there are interruptions in the supply of electricity during winter periods. In terms of electricity consumption per capita, the Kyrgyz Republic ranks 120th out of 133 countries and amounts to 1375 kWh of electricity per year [7].

Prices for 1 kWh of electricity in the Kyrgyz Republic from 2004 to 2014 was 0.7som [7], from 2015 to the present with consumption up to 700 kWh per month is 0.77som, with consumption over 700 kWh per month is 2.16 som for individuals and 2.5 som for legal entities [8].

Geothermal sources have a low cost, so the use of geothermal sources in the Issyk-Kul region is a promising direction to increase the capacity of the energy system. Since the energy potential of renewable energy sources in Kyrgyzstan is significant. According to estimates of the Ministry of Economy of the Kyrgyz Republic and foreign experts, the energy from geothermal sources is 5-10 thousand kWh per year [9,10].Ecology is an important factor in calculating the cost of resources; the cleaner the ecology, the more expensive natural resources are. Sustainability of resources and the natural environment is a necessity.

## VI. Conclusion

The intensive use of the basin's natural resources is unfortunately carried out without proper economic and technical-economic justification and scientific analysis of potential natural opportunities and requirements for the natural environment. The negative consequences of this approach are beginning to be felt now and may be even more significant in the future. On this basis, it is recommended that:

- Build resource-saving technologies, ensure the integrated use of resources, and improve the protection of mineral and thermal water resources.
- Introduce renewable energy sources in agriculture, resorts and tourism facilities, in heating various kinds of buildings and facilities, as well as wide application among the population.
- Improve the management of nature protection in the republic, increase the effectiveness of state control over the state of nature and sources of pollution.

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# Local Actions Roadmap for Climate Change Alleviation in Africa

By Mary Mbenge & Makueni County

*Introduction -* Without doubt, weather patterns are drastically changing. And for the worse. Those aged 70 and above, as opposed to younger generations, can attest to this climate anomaly.

In recent times, hotter temperatures and heat waves, floods, droughts, desertification, erratic rains, rising water levels in lakes and seas (Indian Ocean), melting ice such as on Mt. Kenya and Mt. Kilimanjaro, low groundwater levels, and other adverse climatic effects have been witnessed.

These occurrences usually lead to famines, hunger, poor nutrition, disease, wildfires, deforestation, displacement of people and migration, human-wildlife conflict, air pollution, competition for water and pasture, loss of livestock, soil erosion, locust invasions, loss of biodiversity, deprivation of livelihoods, etc.

Majority of our citizens acknowledge that something awry is happening to their habitat, but are unable to comprehend this phenomenon which commenced in the 1800s especially with the onset of industrialization. Climate change terminology is thus of recent origin.

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# Local Actions Roadmap for Climate Change Alleviation in Africa

Mary Mbenge [α] & Makueni County [σ]

## I. Introduction

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I remember once, the former Makueni County Governor, Prof. Kivutha Kibwana; an ardent environmentalist who in 2006 served as the minister for Environment and natural resources and myself struggled to find a name for climate change in the local dialect. We ended up describing the causes of climate change rather than coming up with a specific name. Finally, we translated the Kiswahili phrase '*mabadiliko ya tabia nchi'* into '*mawaliuku ma mwikalile wa nthi'* to arrive at the Kiikamba name for climate change.

According to the United Nations Framework Convention on Climate Change (UNFCCC, 1992) "climate change means a change of climate which is caused directly or indirectly by human activity that alters the composition of the global atmosphere and which is, in addition to natural climate variability, observed over comparable time periods."

### *a) How Then Does Climate Change Occur?*

Industrialization and other anthropogenic activities produce carbon dioxide related green-house gas emissions. Examples of these actions are: reduction of green spaces to pave way for farming, use of fossil fuels for transportation and energy production, biological waste disposed in landfills, deforestation, charcoal burning etc. These increase the earth's temperatures resulting in global warming.

Global warming of the planet began to be seriously addressed through the UNFCCC.

The 1992 convention recognizes that human activities have substantially increased the atmospheric concentrations of green-house gases, leading to warming of the earth's surface and atmosphere, which may adversely affect natural ecosystems and mankind.

The instrument also notes that the developed industrial countries bear the largest responsibility for green-house gas emissions, whereas the most affected by climate change are the developing poor nations.

The UNFCCC affirms that to combat climate change, co-operation between states is essential and therefore although each country has "the sovereign right to exploit their own resources pursuant to their own environmental and developmental policies," every country has simultaneously "the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other states or of areas beyond limits of national jurisdiction."

From 1995, annual Conference of Parties (COP) have been held to: evaluate progress in dealing with climate change; negotiate the Kyoto Protocol (1997) to establish legally binding obligations for developed countries to reduce their green-house gas emissions; discuss the Paris Agreement (2015) as part of the Durban platform (2011), which created a pathway towards climate action.

In COP 26 in Glasgow, delegates resolved that member states should further strengthen reduction of their carbon emissions, support vulnerable countries with green finance and technology, and assist local communities to build more resilience so as to abate the climate crisis.

Although significant progress has been made in the battle against climate change, there is still a lingering controversy on whether climate change is real or a hoax, and who should shoulder responsibility for addressing and funding the climate emergency.

Currently the climate calamity is perceived as any major global problem of the past and present such as the world wars, nuclear war threat, HIV&AIDs and the more recent COVID-19 pandemics.

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Not all developed UNFCCC member states adhere to the convention. During the Trump era, the USA withdrew from the UNFCCC only for the country under President Joe Biden to embrace the framework. Today, China, Russia and India do resist involvement in global climate commitments, particularly reduced carbon emissions.

Many UNFCCC member states prioritize their right to unhindered industrialization without care about green-house gas emissions. They pit climate action against development, similarly to the earlier jurisprudential discourse on citizens' political and civil rights versus development.

Africa continues to be the epicenter of the climate crisis in terms of the devastation wrecking communities even though it only contributes 3% to the world's carbon dioxide emissions. Therefore, despite our emissions being insignificant, Africa bears the brunt of climate change impact. For instance, Kenya contributes to less than 1 percent of emissions and is number 31 globally in terms of climate change impact.

b) *So what Needs to be Done to Mitigate and Adapt to these Deleterious Effects?*

Mitigation consists of interventions to reduce emission sources or enhance the sinks of green-house gases e.g. alternative energy production, carbon sequestration, increasing tree cover, change in agricultural and water systems, reducing risk from rising water levels in lakes and seas, among other measures.

Adaptation, on the other hand, is an "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (Inter-governmental Panel on Climate Change, 2001) such as building flood dykes, early warning systems, switching to drought-resistant crops, re-designing communication systems, green businesses and reviewing government policies to mainstream climate change as a cross cutting issue.

At the national level, Kenya has been a crusader of climate change response by putting in place various policies, laws, action plans and programmes including the National Climate Change Act, 2016, and the National Drought Management Act, 2016.

c) *What Then is the Climate Action Happening at the Sub-National Level?*

Over 30 counties have climate change policy and legislative frameworks. The rest are in the process of developing the same. Several counties such as Makueni, Kitui, Garissa, Wajir and Isiolo have established climate change fund mechanisms. A few counties have established ward climate change planning committees. These grass root structures are the most effective way to implement locally-led climate actions that have a sure global impact from local actions.

The just concluded 7th Annual Devolution Conference in Makueni county, themed 'Multi-Level Governance for Climate Action' aligned with the global call for climate change post COP 26. The focus of the discussion was how to cushion vulnerable communities affected by climate change. The elephant in the room was how to mobilize adequate resources to undertake the challenge.

The Makueni conference resolutions are to guide the National Government and County Governments to cooperate and implement practical policies and action plans to address climate change. Both levels of Government resolved to strengthen inter-governmental consultations on agriculture, increase budgetary allocations to climate actions and provide early warning systems.

During the conference a World Bank project dubbed 'Financing Locally –led Climate Action (FLoCCA)' was launched. This will avail much needed resources to assist communities build climate change resilience by using the local set up climate change structures.

Ultimately, individual commitment to climate action is critical. For example, to achieve the designated 10 percent tree cover, each Kenyan should grow a tree or preferably trees their age.

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# Hydrochemical Assessment of Surface and Groundwater in Some Selected Communities of Borno and Yobe State

By S. Adamu, H. M. Sadiq, A. K. Yusuf, M. M. Aji & M. Muhammad

*University of Maiduguri*

*Abstract-* The study area comprises three communities of Ala, Daura in Borno State and Kyalari in Yobe State, North-eastern Nigeria which forms part of the Chad Basin. Twenty five (25) water samples were collected from major sources which comprises of nine (9) hand dug wells, ten (10) surface water and six (6) boreholes. The physical parameters analyzed revealed pH values ranging from 6.5 - 8.1 and electrical conductivity varies between 67 – 1050m$\mu$/cm. The results of the chemical parameters shows that Ca2+ ranges between 3.5 to 66.5mg/l, while Mg2+ varies from 4.8 to 28.2mg/l, Na+ and K+ varies between 0.7 to 1241.0mg/l and2.0 to 112.0mg/l respectively. HCO3- ranges from 77.5mg/l to 337.0mg/l while Cl- varies from 4.0 to 160.0mg/l. The concentration of SO4- varies between 0.7mg/l to 283.0mg/l. This study confirms that they are normal for domestic, agricultural and small scale irrigation purposes. The study shows that some cation and anion are within WHO limits of 2020 permissible limit of drinking water standard except for WARODI wells which show abnormally higher values above the WHO standard.

*Keywords:* *surface water, groundwater, concentration, communities, boreholes, hand dug wells and warodi.*

*GJSFR-H Classification:* *DDC Code: 628.4 LCC Code: GE300*




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# Hydrochemical Assessment of Surface and Groundwater in Some Selected Communities of Borno and Yobe State

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*Keywords: surface water, groundwater, concentration, communities, boreholes, hand dug wells and warodi.*

## I. Introduction

Three communities of Ala in Marte local government and Daura in Damasack local government of Borno State and Kyalari in Yunusari local government of Yobe State located within the Nigerian sector of the Lake Chad Basin within latitudes $11^{0}25^{1}$ to $13^{0}$ $30^{1}$N and longitudes $11^{0}35^{1}$ to $14^{0}$ $00^{1}$ E (Figure 1).

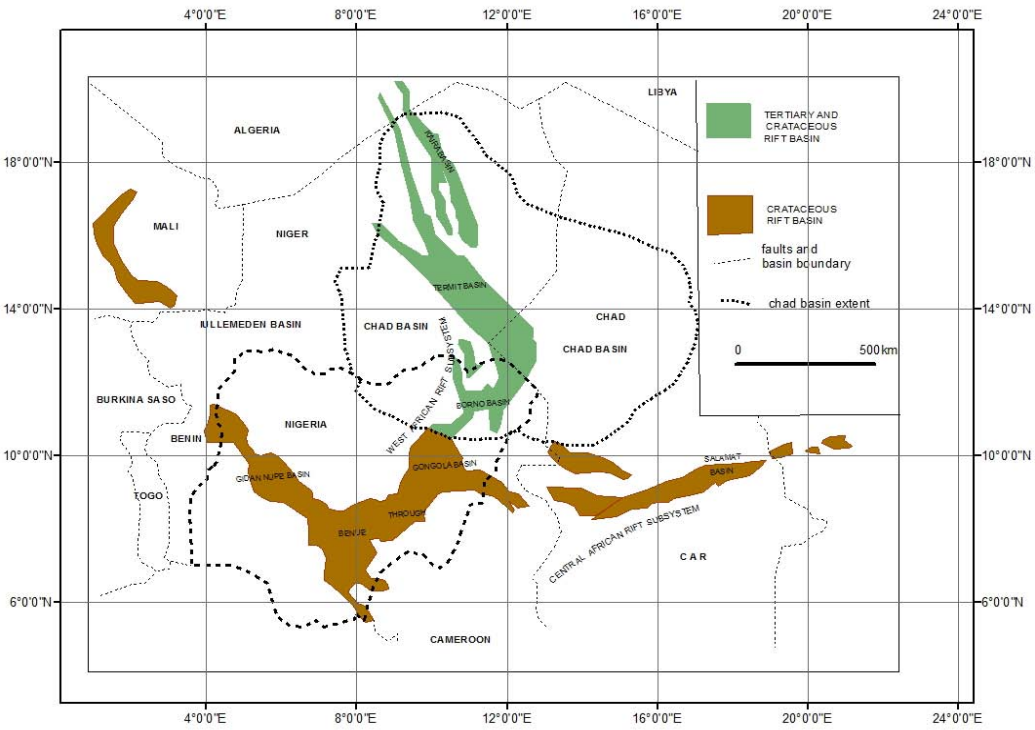


*Figure 1:* Location of the Study Area ( After Genik, 1993)

The study area is wholly underlain by the sedimentary rocks dominated by late Plio-pleistocene Chad Formation, consisting of interbedded clays, silts and subordinates sands of continental origin probably

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up to 1000 m thick (Schoeneich, 2001). Today, there is a global concern about pollution as the major causes of ill health where the state of the water is control by its migration characteristic and temperature gradients. The simplest classification of water is based on the total concentration of dissolved solids measured in milligram per liter (mg/l). Water is considered to be polluted when it is not suitable for specified purpose. Thus, the quality of water varies with use to which it is put. Domestic waste and industrial activities are the major sources of water pollution, though pollutants may also enter water through air and oil migration. Generally therefore, the nature of polluted water will depend very much on the area in which it is located (Eduvie, 1991). The effects of pollution in water include color change, alteration of pH, alteration of amount of free solids, the level of biochemical and chemical oxygen demands. The above changes have critical effects on life processes (Sani, 2016).

According to (WHO, 2020) water once polluted, becomes poisonous to aquatic plants and animals and the successive ecosystem either directly or as a results of the food chainthe ingest the pollutants and gradually accumulate same in their bodies to the point of being toxic and in extreme cases may causes death. Extensive research conducted in various parts of the world such as Hem (1985), Okagbue (1988) and Todd (1980) have documented a large body of inorganic elements which so far are considered essential in human nutrition and play vital roles as structural and functional components of metalloproteinase and enzymes in cellular processes. This paper attempts to look into the major elemental concentration of the various water sources in three communities located within the Nigerian sector of Chad Basin with the aim of assessing their chemistry and suitability for domestic, animal and small scale irrigation purposes.

## II. Topography and Drainage

The study area is generally featureless characterized by flat alluvial Holocene landmass, with scanty outcrops of Pleistocene Chad Formation, which gently dips northeast towards Lake Chad. The only features which break the flat terrain are sand dunes in the north west part of the study area as well as the 260 km long and 5 - 6 metre high prominent sand ridge named “Bama Ridge,” considered to be formed at the shore of Mega – Chad Lake in the early Holocene, some 10,000 years ago (Zarma et al, 2015). In essence, the Bama Ridge separates flat depositional land in the north east from slightly undulating erosional surface in the south west. As observed from this study, Bama Ridge may have tectonic predisposition. The sand dunes occupy mostly Gudumbali, Kukawa, Ngazai, and Damasck. Hummocky type of sand dunes with high topographic elevation is also found close to Geidam as observed during the field work.

The inter-dunal valleys were covered by clay beds with the sand ridge traceable to about 40 km in west and southwest of the study area. The ridges are clearly seen around Gubio, Magumeri, Maiduguri and towards Bama it extend to Banki area within the study area. The ridge is probably an ancient Holocene shoreline of the Lake Chad which dip at an angle of $5^0$ (Zarma et al, 2015).

The drainage system of the area is characterized by the Hadeja-Yobe River System and the Ngadda, Yedseram and Komadugu-Gana River System all flowing toward Lake Chad. Most of these rivers are influent streams that end in inland deltas (Figure 2). None of the rivers is perennial or effluent in nature and most of them flows into marshy area on the plain and disappear by evapotranspiration before reaching Lake Chad. However, the Komadugu-Yobe in the northwest and the Yedseram River to the southeast are relatively large rivers that discharge into Lake Chad during the wet season. In the northern part of the study area, the Komadugu-Yobe passes through the sand dunes in a narrow flood plain which is marked by larger alluvial tracks on the inner bends of the river.

Flooding of these tracks by the overflow from the river creates permanent marshy lands. Although near Lake Chad, the flood plain fans out in several tributaries with scattered marshy areas and Cut-off River meanders. The Komadugu-Yobe River begins to flow in June or July and reaches its peak discharge in August and October. After the wet season, discharge from Komadugu, Yedzaram and Ngadda decreases rapidly with patch of pools of water remaining in the main stream channels. The Komadugu Goma River joins the River Goa as a tributary to River Forunduma which joined River Forunduma Gana as tributaries and finally empties its water into the Lake Chad. River Kaha and River Dorma are also part of tributaries to River Forunduma which empties its water into Lake Chad (Figure 2).

The Yedseram River which flows through Bama has a relatively small catchment area its flow, which is seasonal usually begins in July at the Bama area because of long distance of the river meander channels flowing from Republic of Cameroun through Adamawa State before reaching Bama area and ceases to flow by December. The river breaks up into a series of braided channels and deltas flowing across the extensive fadama around Dikwa, Marte and Monguno area and finally emptying into Lake Chad (Fig: 2).

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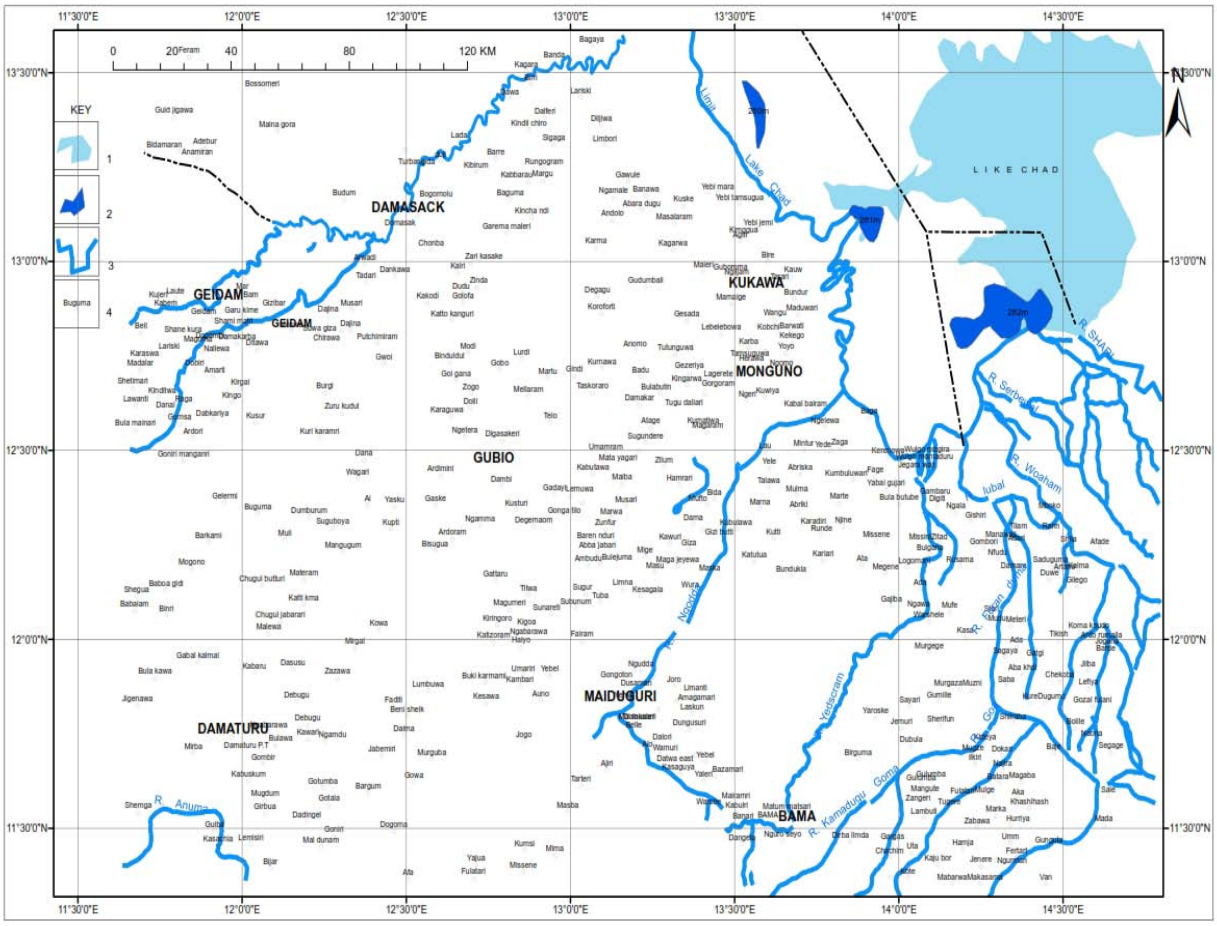


*Figure 2:* Drainage Map of the Study Area (Modified After Geological Survey, 1960)

The Ngadda River cuts through the Bama Ridge at Maiduguri in a well-developed channels and flows through a system of braided channels. Further north, the river gradually loses its identity as it fingers out on a marshy plain to form deltas bars which joint the Jere bowl. Upstream from Maiduguri, the Ngadda River passes through Lake Alou, a seasonal lake. The surface area of the Lake Alou is about 4 square kilometres. The Lake receives its water during wet season from delta fans spread from far southern part of the study area without a clear river or channels (Figure 2). While Amanna River, initially flowing to Lake Chad and later, after formation of Bama ridge it diverted its channel into Gongola River.

According to Schoeneich (2004), Water present in the study area consists of both atmospheric, surface and groundwater. The atmospheric water is mainly derived from rainfall which progressively falls from 800 mm/a in the southern part of the study to about 400 mm/a to the northern part of the study area. (Schoeneich, 2004) is of the view that, there is no recharge taking place if depth of annual precipitation is less than 700 mm/a (Fig. 3).



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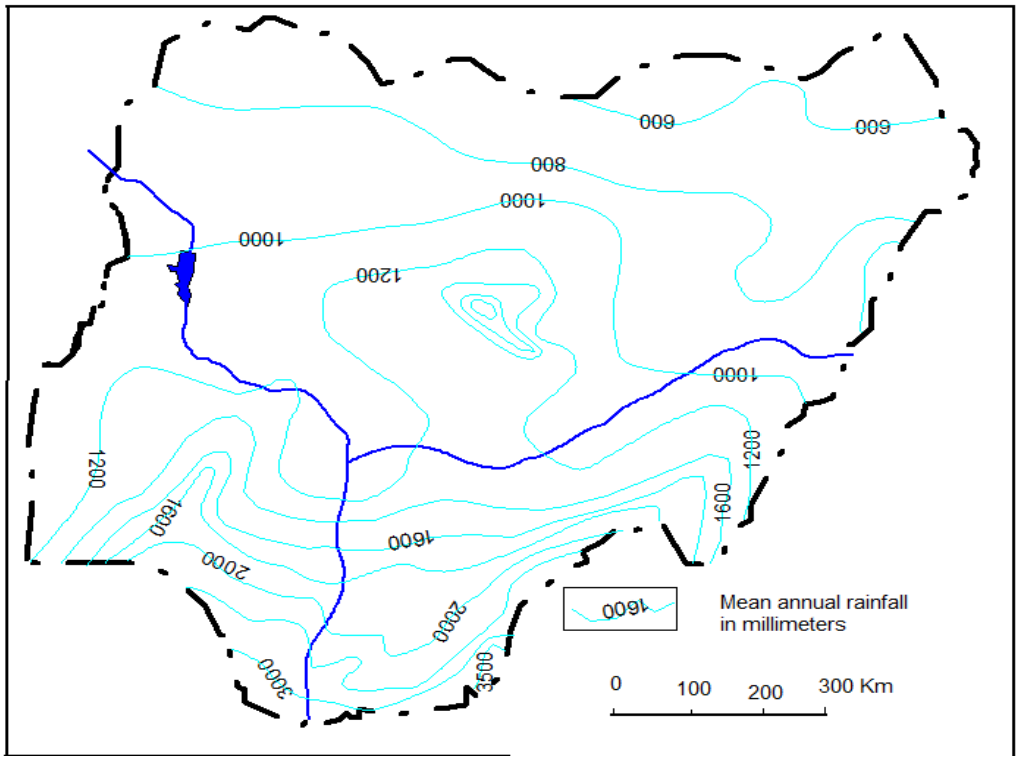


*Figure 3:* Map of Annual Depth of Rainfall in Nigeria (After Schoeneich, 2004)

The groundwater in the research area is contained mainly in the Chad Formation with the greater part of the groundwater (7817km$^3$) is salty water with only the upper most part consisting of 1713km$^3$ being fresh water according to (Schoeneich, 2001). This fresh water occurs mainly in the Chad Formation within three geologic formations namely the Upper, Middle and Lower Aquifers (Fig. 4)

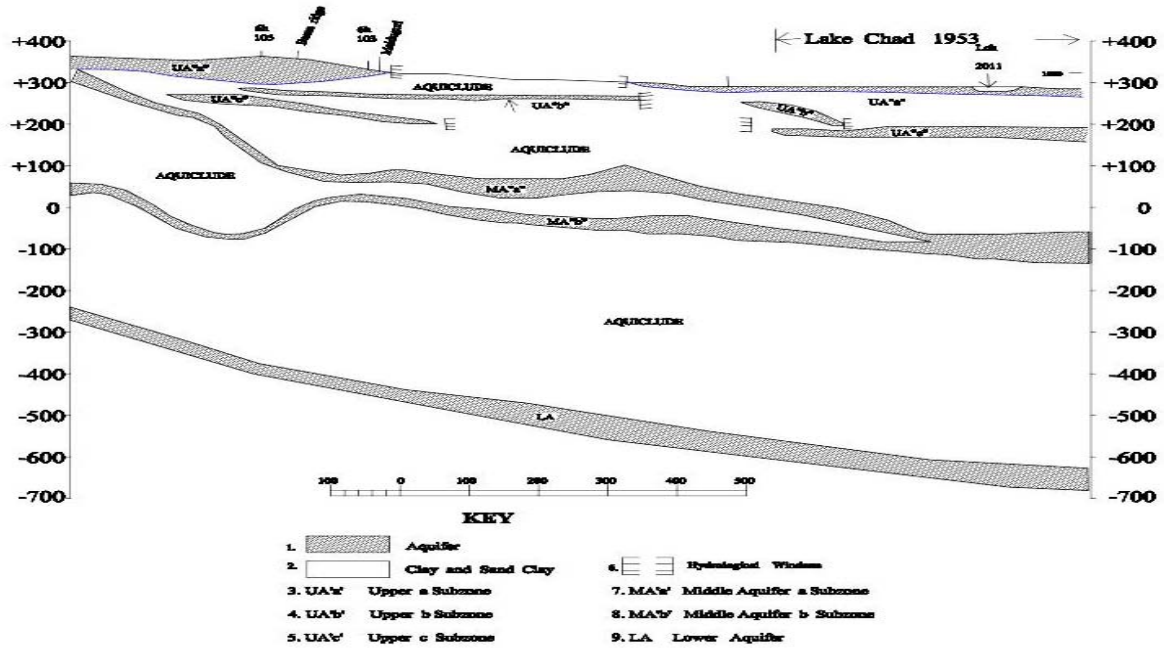


*Figure 4:* Map of Hydrogeological Cross-Section A-B of Chad Formation Showing the Three Aquifer, (Upper, Middle and Lower Aquifer) the Middle Aquifer is Separated into A and B Subzone (After Sani, 2016)

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## III. Geological Setting

According to Kogbe (1976) and Avbovbo (1986) the geological history of the area started in the Upper Albian with the deposition of mainly marine sometimes deltaic and fluviatile interbedded clays, silts and sands (Fig: 5). It is possible that after Maastrichtian, this sedimentation continued up to Paleocene leaving the continental series of sandstones interbedded with claystones and siltstones called Kerri-Kerri Formation.

There was no evidence of deposition after that until almost late Pliocene when sedimentation resumed and lasted without interruption to date. The product of this deposition is what is referred to as Chad Formation which consists of interbedded clays, silts and subordinate sands of continental origin measuring up to 1000 m in thickness (Carter et al, 1963, Kogbe, 1992 and MacDonald et al, 2005).

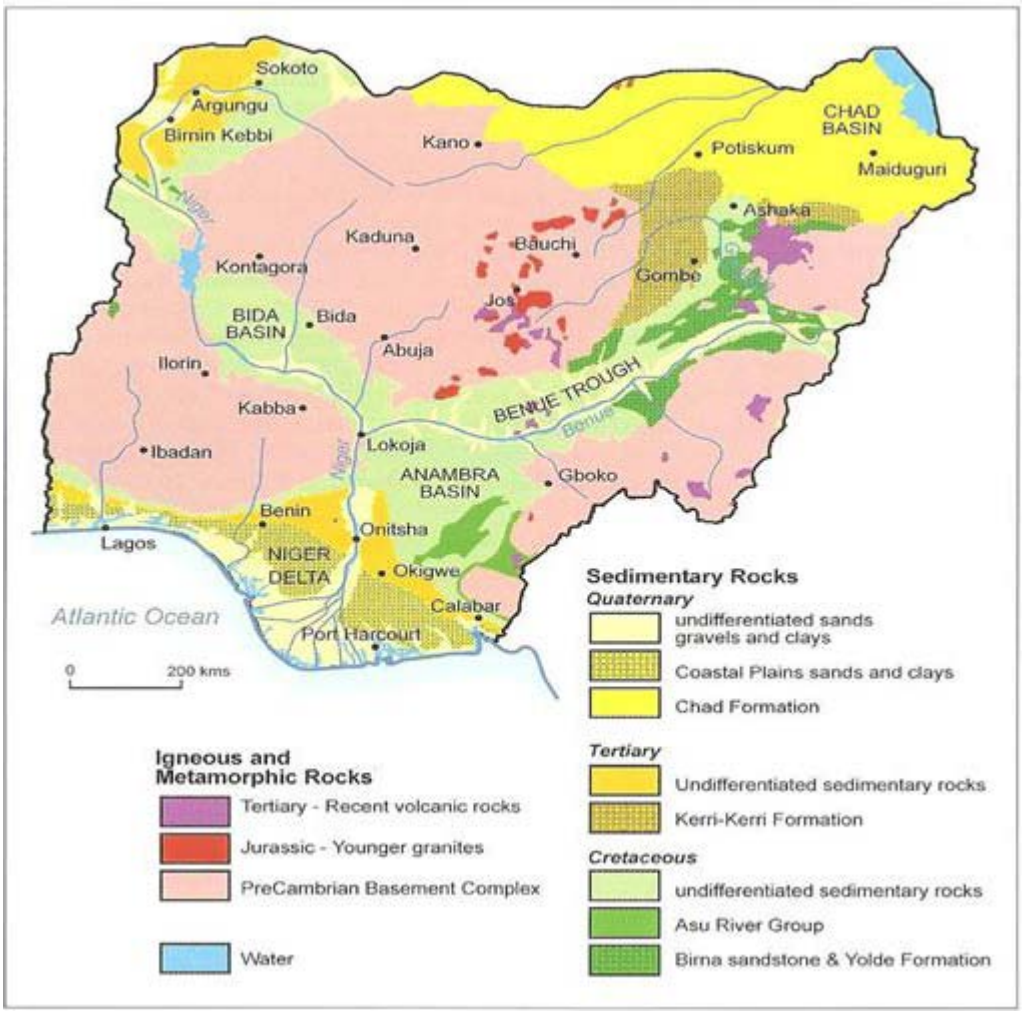


*Figure 5:* Generalized Geological Map of Nigeria (After MacDonald *et al.*, 2005)

## IV. Material and Methods

Twenty five (25) water samples were collected which comprises of nine (9) hand dug wells, ten (10) surface water and six (6) from boreholes. These constitute the major source of water supply in the research area. The top film of the surface water and groundwater were removed, twolitres of water samples was then collected in clean dry plastic bottles filled completely and cap tight to avoid excessive agitation or exposure to sunlight. Each sample was then labelled and preserved in the refrigerator until when they are ready for chemical analysis. The position of each sample location was taken using Global Positioning System (GPS) Garmin type. Physical parameters of the samples suchus electrical conductivity, temperature, total dissolve solid and hydrogen exponent were measured directly on the field at spot. The analytical method employed includes Atomic Absorption and Spectrometer which was adopted for the analysis of $Mg^{2+}$ and $K^{2+}$. While digital titration method were used in the determination of $SO_4^-$, $HCO_3^-$ and $Cl^-$. The flame photometer was used in determining $Ca^{2+}$ and $Na^+$ respectively (Figure 6).



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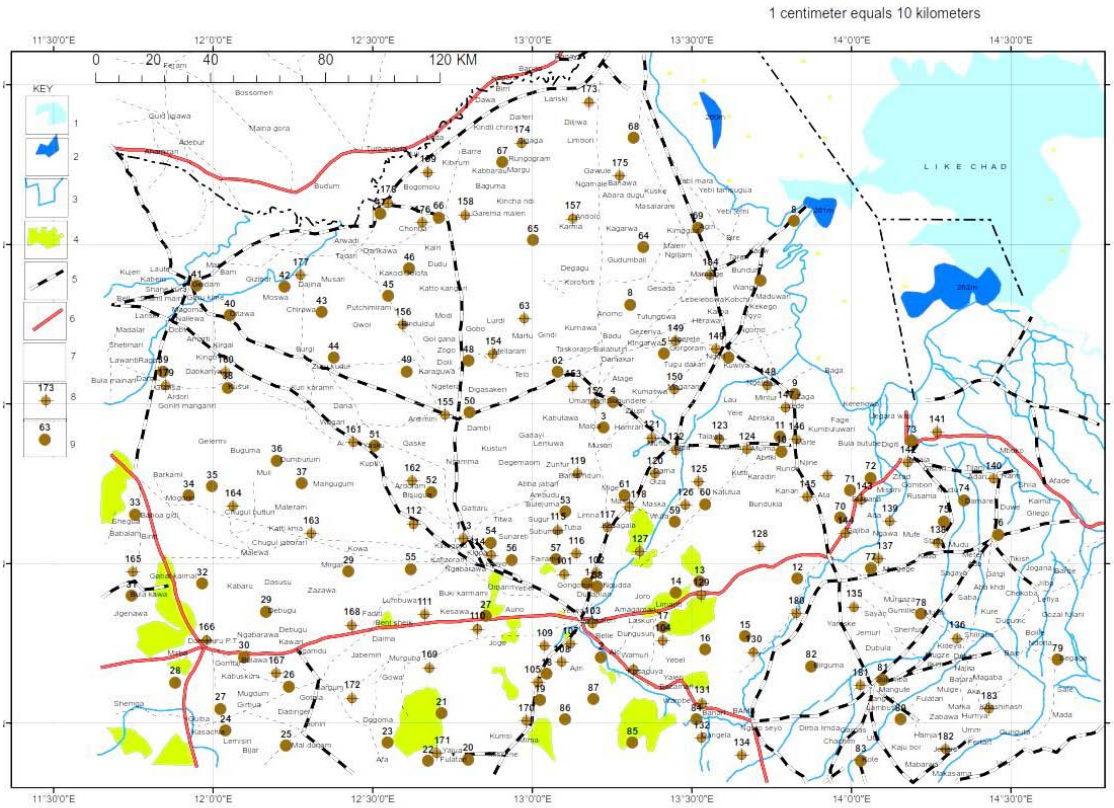


*Figure 6:* Distribution of the Sample Locations in the Study Area

## V. Discussion

The results of the water analyzed is presented in table one and two (1 and 2) below. From the result of physical parameters measured, it can be read as follows pH ranges from 6.5 to 8.1 while electrical conductivity (EC) varies from 67 to 1050m$\mu$/cm respectively. The results of temperature also varies from 28 to 39$^{oc}$ with 33. 4$^{oc}$ as overall means of the temperature both in surface and groundwater but the temperature in groundwater are higher due to increase in depth (Table 1). The results of chemical parameters measured in milligram per liter shows that, $Ca^{2+}$ ranges from 3.5 to 66.5 mg/l while that of $Mg^{2+}$ varies between 4.8 to 28.2 mg/l. The $Na^{+}$ and $K^{+}$ values ranges from 0.7 to 1241.0 mg/l for $Na^{+}$ and 2.0 to 112.0 mg/l for $K^{+}$ respectively. The concentration of $HCO_3^{-}$ in the water varies between 77.5 to 237.0 mg/l while that of $Cl^{-}$ ranges from 4.0 to 160.0 mg/l. The value of $SO_4^{-}$ in the water varies from 0.7 to 283.0 mg/l. The mean concentration of the cations show that $Na^{2+} > Ca^{2+} > K^{+} > Mg^{2+}$ respectively.

From the results, studies reveal that, sodium has the highest concentration in the water as observed from Warodi well 24 and well 25 with the concentration of 814.0 and 1241.0 mg/l this high concentration may reflect the geochemical interaction of transported materials with those occurring in the area while calcium concentration may be attributed to its abudance in the earth crust or are released as weathered products of feldspers, amphiboles and pyroxenes. Magnesium may have been sourced from amphiboles, pyroxenes, or olivines from the basement rocks or from clay minerals derived from such rocks (Elueze et al, 2001).

The source of HCO3- which has a mean concentration of 129.7mg/l (Table 1 and 2) can be attributed to CO2 charge waters (Tijjani, 1994) while the warm temperature of groundwater observed in boreholes and hand pumps up to 39$^{oc}$ is attributed to the fact that the groundwater in such areas occurs within the middle confined aquifers of the Chad Basin and temperature increases with depth (Barber and Jones, 1965). The chloride concentration in the water with average of 54.2mg/l suggests that the chemical characteristics of the water are influenced by recharge from meteoric water as observed from hand pumps due to its shallow depth and mostly phreatic aquifer or the weathering and release of ions from the underlying basement rocks (Olayinka et al, 1999 and Sani, 2006) The high values of physical parameters such as EC, pH and temperature in the groundwater as compared to surface water may be due to incorporation of dissolved components of overburden and anthropogenic influences arising from contamination.

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*Table1:* Physico-Chemical Mean Data of Surface and Groundwater Compared with WHO, 2020 Standard

| Measured parameters | Ranges | Groundwater | Surface water | Overall mean | Acceptable level | Excessive level |
|---|---|---|---|---|---|---|
| Temperature | 28 -39 | 34.2 | 32.2 | 33.4 | - | - |
| pH | 6.5 – 8.1 | 7.18 | 7.89 | 7.46 | 6.5 | 6.5 – 8.5 |
| EC | 74 - 1050 | 548.53 | 235.1 | 423.16 | - | - |
| $Ca^{2+}$ | 3.5 – 66.5 | 37.57 | 11.84 | 27.28 | 75 | 200 |
| $Mg^{2+}$ | 4.8 – 28.2 | 13.6 | 9.21 | 11.84 | 125 | 150 |
| $Na^{+}$ | 0.7-1241.0 | 178.51 | 13.50 | 112.50 | 120 | - |
| $K^{+}$ | 2.0 -112.0 | 31.01 | 10.11 | 22.65 | 200 | - |
| $HCO_3^{-}$ | 77.5-237.0 | 136.77 | 119.20 | 129.74 | 200 | - |
| $Cl^{-}$ | 4.0-160.0 | 67.73 | 33.80 | 54.16 | 250 | 600 |
| $SO4^{-}$ | 0.7-283.0 | 90.09 | 25.01 | 64.06 | 200 | 400 |

*Table 2:* Physical and Chemical Characteristic of Surface and Groundwater in Parts of Chad Basin Nigeria

| Sample No | Source of water | pH | Temperature (o°) | Electrical conductivity (mμ/cm) | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ | $HCO_3^{-}$ | $Cl^{-}$ | $SO_4^{2-}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DAURA 1 * | Groundwater | 8.0 | 33 | 381 | 22.4 | 10.6 | 13.6 | 6.0 | 105.0 | 6.0 | 46.8 |
| MELERI 4* | ,, | 7.3 | 33 | 252 | 53.0 | 9.6 | 66.0 | 9.0 | 187.0 | 34.0 | 85.6 |
| KANARAM 5 * | ,, | 7.4 | 32 | 306 | 25.6 | 14.0 | 25.6 | 4.0 | 144.5 | 16.0 | 56.9 |
| BULABULIN7 * | ,, | 7.5 | 33 | 241 | 9.2 | 17.0 | 9.5 | 4.6 | 90.5 | 28.0 | 9.0 |
| NJOLLOM 8 * | ,, | 7.4 | 32 | 400 | 26.2 | 7.3 | 68.5 | 10.5 | 143.5 | 24.0 | 15.7 |
| BAGADA 9 * | ,, | 7.5 | 33 | 254 | 11.4 | 12.5 | 6.0 | 8.5 | 95.0 | 18.0 | 2.6 |
| ALI BANYE 10 ** | ,, | 6.5 | 39 | 1050 | 49.0 | 6.0 | 75.0 | 13.6 | 98.0 | 160.0 | 96.0 |
| MARTE 12 ** | ,, | 6.5 | 39 | 984 | 57.0 | 17.0 | 71.4 | 10.0 | 179.0 | 130.0 | 76.0 |
| ALI MARTE 14 ** | ,, | 6.8 | 35 | 1012 | 63.0 | 13.5 | 102.4 | 12.7 | 191.0 | 120.0 | 100 |
| KANZOMO 15 ** | ,, | 6.7 | 36 | 1002 | 33.6 | 12.3 | 75.4 | 13.6 | 133.5 | 94.0 | 68.3 |
| MUSSENE 16 ** | .. | 6.7 | 37 | 906 | 66.5 | 11.0 | 74.3 | 12.0 | 237.0 | 80.0 | 97.5 |
| KALARI 21 *** | ,, | 7.7 | 34 | 138 | 8.4 | 16.7 | 8.0 | 2.0 | 122.5 | 12.0 | 0.7 |
| KALARI FULANI 22 * | ,, | 7.3 | 33 | 502 | 33.4 | 4.8 | 27.0 | 30.4 | 78.0 | 30.0 | 188.2 |
| WARODI 24 * | ,, | 7.3 | 31 | 400 | 48.2 | 9,4 | 814.0 | 102.2 | 138.5 | 120.0 | 224.8 |
| WARODI 25 * | ,, | 7.1 | 31 | 400 | 56.7 | 27.5 | 1241.0 | 112.0 | 108.5 | 144.0 | 283.0 |
| DAURA 2 **** | Surface water | 8.3 | 36 | 562 | 26.0 | 25.4 | 25.0 | 37.5 | 220.0 | 96.0 | 134.7 |
| DAURA 3 ***** | ,, | 7.3 | 32 | 74 | 3.5 | 28.2 | 3.6 | 3.8 | 87.0 | 56.0 | 6.0 |
| KANARAM 6 **** | ,, | 8.3 | 36 | 127 | 27.0 | 8.4 | 72.2 | 11.0 | 216.0 | 44.0 | 12.6 |
| MARTE 11 **** | ,, | 8.1 | 28 | 215 | 4.5 | 11.0 | 18.1 | 13.0 | 98.0 | 44.0 | 8.5 |
| NEW MARTE 13 **** | ,, | 7.9 | 29 | 795 | 11.8 | 5.7 | 12.4 | 2.7 | 87.0 | 18.0 | 9.4 |
| NEW MARTE 17 ****** | ,, | 8.0 | 33 | 268 | 23.7 | 10.0 | 12.4 | 14.0 | 111.0 | 56.0 | 34.6 |
| KALARI 18 ***** | ,, | 8.1 | 32 | 67 | 4.5 | 7.5 | 2.5 | 2.7 | 77.5 | 4.0 | 17.2 |
| KALARI 19 ***** | ,, | 7.6 | 31 | 81 | 5.6 | 5.0 | 6.8 | 4.6 | 112.5 | 4.0 | 7.0 |
| KALARI 20 ***** | ,, | 7.7 | 32 | 81 | 5.8 | 5.5 | 5.0 | 6.8 | 87.0 | 4.0 | 11.0 |
| KALARI 21 ***** | ,, | 7.6 | 33 | 81 | 6.0 | 5.8 | 2.0 | 5.0 | 96.0 | 12.0 | 9.1 |

**Hand dug wells**Boreholes ***Hand pumps ****Stagnant surface water *****Flowing River*



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## VI. Water Types

Water can be classified chemically base on the mineralization of ionic contents ( Schoeneich, 2001) states that, water can be classified chemically based on mineralization prevailing mega-ions and some trace elements or some dissolved gases. Therefore water can be classified either on Piper trillinear diagram, Wilcox diagram, Schoeller plot or other parameters.

Piper diagram was produced based on the values of the major elements analyzed from the water samples. A plot of cations and anions were done on triangle and was projected in a diamond shape representing both anions and cations, from the plot; water type is classified base on water sampled collected from surface water, impounded surface water pond, flowing River and groundwater tapping Upper aquifer through hand dug wells and boreholes tapping Middle aquifer.

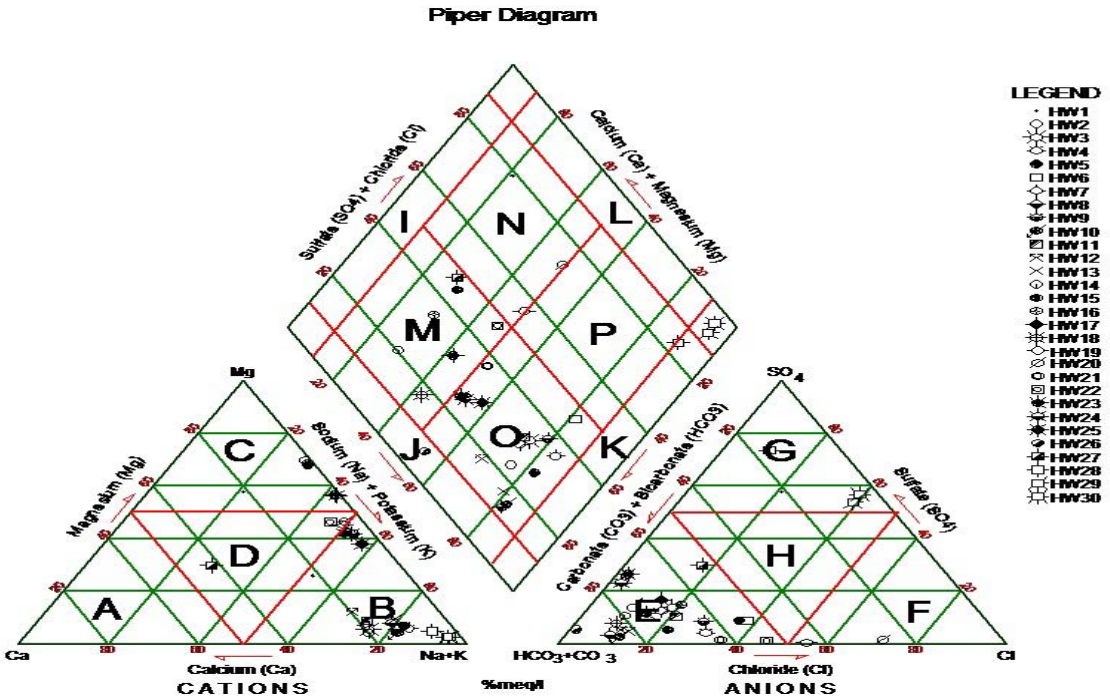


*Figure 7a:* Piper Trillinear Plot Diagram Representing the Analyses of Water Types from Surface Water and Phreatic Aquifer within the Study Area



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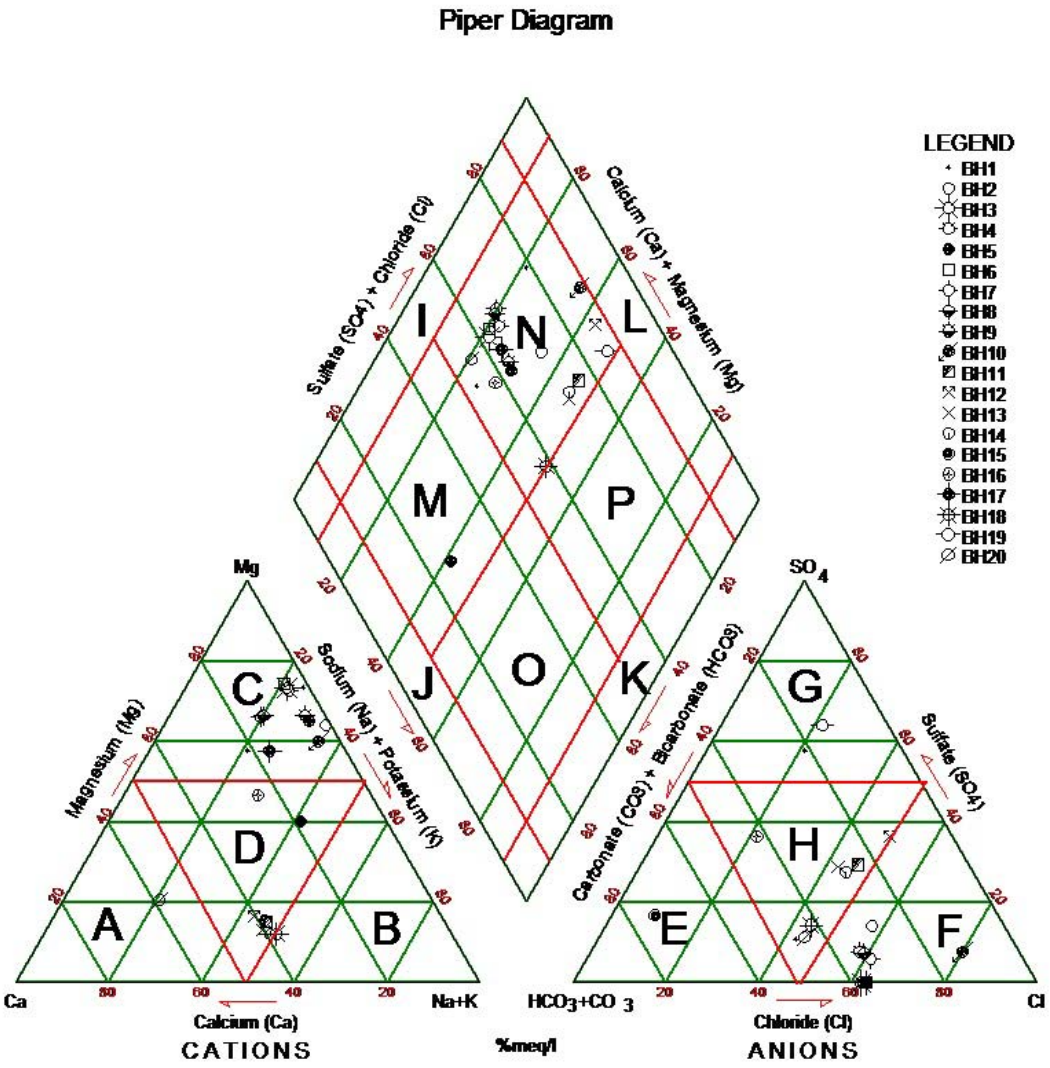


*Figure 7b:* Piper Trillinear Plot Diagram representing the Analyses of Water Types Tapping Middle Aquifer within the Study Area

From the two results plotted on piper trillinear diagram of the study area (Black and Hanshow, 1965). A = Calcium type; B = Sodium or Potassium type; C= =Magnesium type; D = No dominant type; E = Bicarbonate type; F = Cloride type; G = Sulphate type; H = No dominant type; I = Ca+Mg type; J = HCO3 +CO3 type; K = Na +K type; L = Cl = SO4 type; M = Ca(Mg) HCO3 type; N = Ca(Mg) ClSO4 type; O = Na(K) HCO3 type and P = Na(K) Cl(SO4) type. Water around Kalari and Warodi is more of Sodium and potassium rich with Sulphate bicarbonate ions and became the dominant water type of $NaSO_4HCO_3$ while the southern part of the study area is rich in $NaHCO_3SO_4$ water type.

Piper plot is useful for showing multiple and trends in major ions. It divides water into types according to their placement near the four corners of the diamond triangle. Water that plots at the top of the diamond is higher in $Ca^{2+}$ + $Mg^{2+}$ and $HCO_3^-$ and is the region of waters with temporary hardness.Water plotted at the lower corner of the diamond is composed primarily of $Na^+$ + $K^+$ and $HCO_3^-$.It represents the combination of major and minor constituents of groundwater in the study area. According to the diagram, sodium and potassium is the dominant and calcium is the least in hand dug wells tapping Upper aquifer while in boreholes tapping Middle aquifer, calcium is the dominant element and the potassium is least.

According to Furtak and Langguth (1967) it can be deduce based on percentage with 53% of the water in the area belong to earth alkaline type with higher alkaline proportion while 41% belong to or fall within acidic water type with only 5% being normal for domestic consumption.

This work is further plotted on Schoeller plot, is a semi-logarithmic plot to represent major ion analyses in milliequivalents per liter and to demonstrate different hydrochemical water types on the same plot. Schoeller diagram represents the combination of major and minor



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constituents of groundwater and surface water in the study area. According to the diagram, sodium is the dominant and calcium is the least in hand dug wells tapping Upper aquifer while in boreholes tapping Middle and Lower aquifer, magnesium is the dominant element and the chloride is least in the plot as presented below in Figure 8a and 8b.

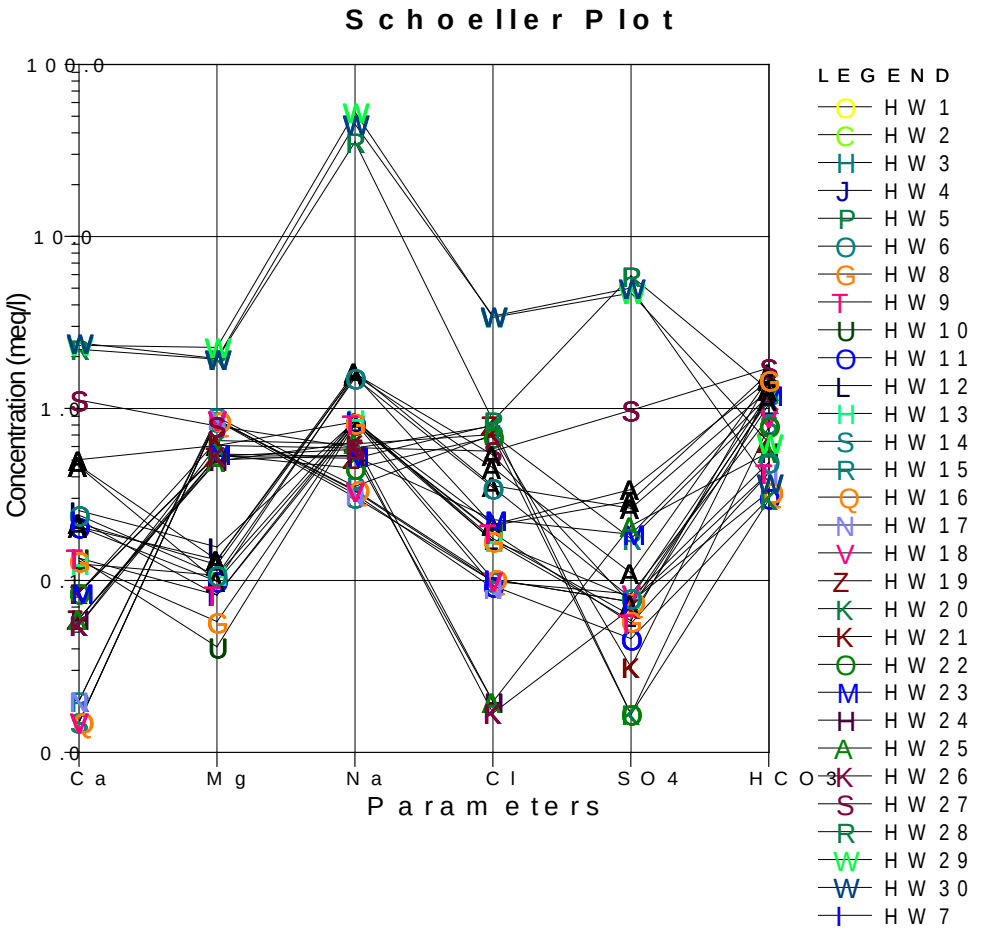


*Figure 8a:* Results of water quality Plotted on Schoeller Diagram Tapping Upper Aquifer in Hand Dug Wells



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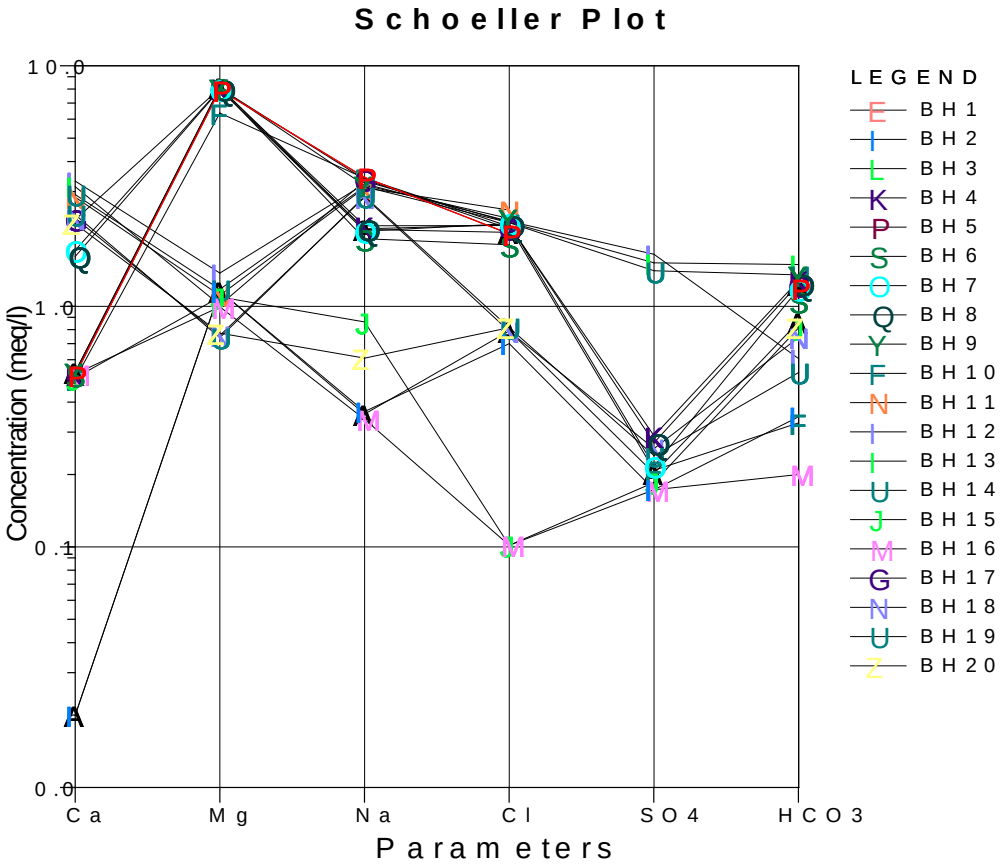


*Figure 8b:* Results of Water Quality Plotted on Schoeller Diagram Tapping Middle and Lower Aquifer in Boreholes

a) *Suitability of water for drinking, domestic use and agriculture based on its major ions*

The first thing to think about the Basin is that, is there enough water to drink both for domestic uses and livestock rearing before talking of small scale irrigation. This is the question to answer before talking about its suitability of the water in the research area. In fact there is no enough water for consumption. The only available water in the study area is little water from A and B sub-zones in Upper aquifer bed with sodium, magnesium and sulphate are higher above the WHO, 2021 limit as detected from analyses of water samples.

Wilcox plot enable water to be classified base on the conductivity of the water analysed in the study area. From the Wilcox plot it can be read that, one of the sample is excellent for irrigation with low sodium hazard with conductivity $<$ 250 $\mu$S/cm while ten of the samples are good for irrigation with conductivity between $<$ 250 – 750 $\mu$S/cm and five of the sample are moderatly good for irrigation with conductivity between 750 – 2250 $\mu$S/cm in the Upper aquifer tapping through hand dug wells. In the borehole tapping Middle and Lower aquifer, five of the samples is excellent for irrigation with low sodium hazard with conductivity $<$ 250 $\mu$S/cm while twenty of the samples are good for irrigation with conductivity between $<$ 250 –750 $\mu$S/cm, This means that the water in deeper Chad Formation is more conductive than those in the phretic zone as a result of higher total dissolve solid ( Figure 9a and 9b).



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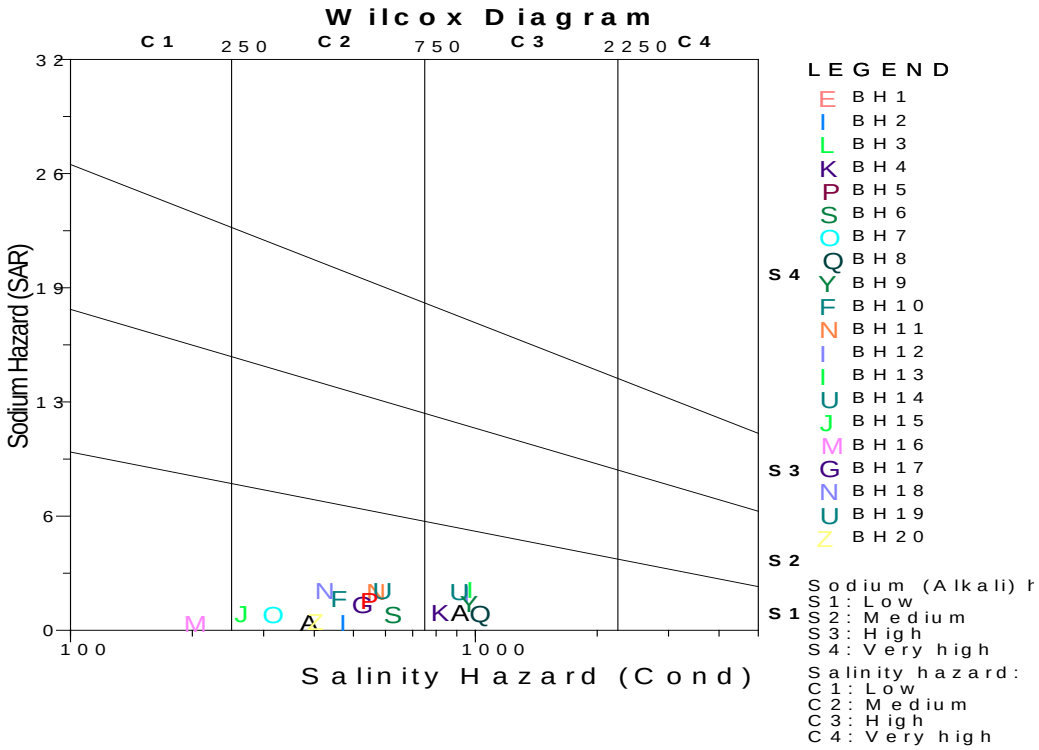


*Figure 9a:* Wilcox Plot of Hand Dug Wells Tapping Upper Aquifer in Chad Formation



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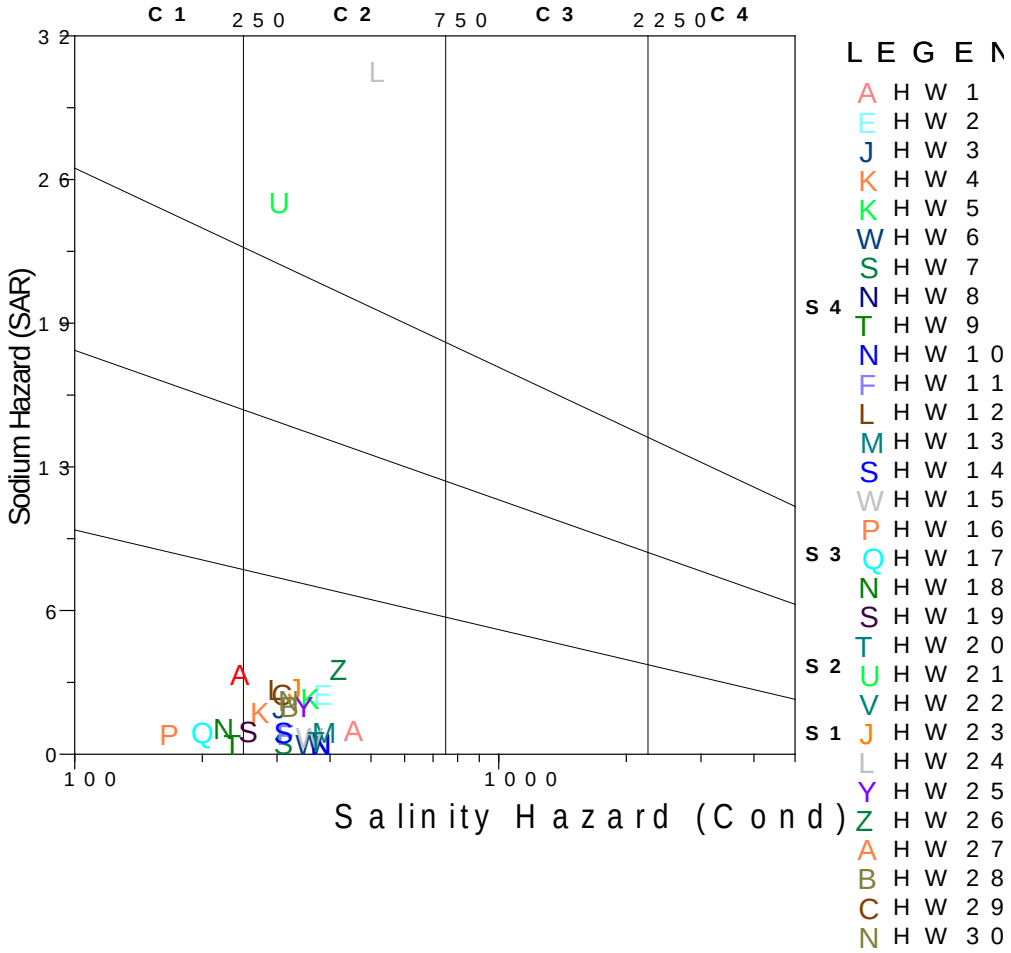


*Figure 9b:* Wilcox Plot of Boreholes Tapping Middle and Lower Aquifer

## VII. Conclusion

Results of hydrochemical studies of both surface and groundwater in parts of the Chad basin shows that the water is acidic and alkaline. The study further reveals that the Warodi wells 24 and 25 is highly enriched in sodium and other anions which are above the permissible limits (WHO, 2020) which may cause laxative effect such as gastrointestinal pains thereby leading to death in most cases. This has been confirmed in this study as animals that drank the water from this wells died instantly according to the villagers and so all the wells were abandoned. Further research may be required for the confirmation of this to ascertain the result of higher pollution of the wells in the area. It may be also recommended that, other water sources be developed to supplement the existing ones and also the need to advance this research to microbial, heavy metals and isotopic studies is necessary to ascertain the reason for higher major elements in the wells.

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Associates are authorized to organize symposium/seminar/conference on behalf of Global Journal Incorporation (USA). They can also participate in the same organized by another institution as representative of Global Journal. In both the cases, it is mandatory for him to discuss with us and obtain our consent. Additionally, they get free research conferences (and others) alerts.

Career | Credibility | Financial

## Early Invitations

### Early invitations to all the symposiums, seminars, conferences

All associates receive the early invitations to all the symposiums, seminars, conferences and webinars hosted by Global Journals in their subject.

Exclusive




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### Earn 30-40% of sales proceeds

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Exclusive | Financial

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### Get a remuneration of 15% of author fees

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Financial

## And Much More

### Get access to scientific museums and observatories across the globe

All members get access to 2 selected scientific museums and observatories across the globe. All researches published with Global Journals will be kept under deep archival facilities across regions for future protections and disaster recovery. They get 5 GB free secure cloud access for storing research files.

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| Associate | Fellow | Research Group | Basic |
|---|---|---|---|
| $4800<br>**lifetime designation** | $6800<br>**lifetime designation** | $12500.00<br>**organizational** | APC<br>**per article** |
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# Preferred Author Guidelines

**We accept the manuscript submissions in any standard (generic) format.**

We typeset manuscripts using advanced typesetting tools like Adobe In Design, CorelDraw, TeXnicCenter, and TeXStudio. We usually recommend authors submit their research using any standard format they are comfortable with, and let Global Journals do the rest.

Alternatively, you can download our basic template from https://globaljournals.org/Template.zip

Authors should submit their complete paper/article, including text illustrations, graphics, conclusions, artwork, and tables. Authors who are not able to submit manuscript using the form above can email the manuscript department at submit@globaljournals.org or get in touch with chiefeditor@globaljournals.org if they wish to send the abstract before submission.

## Before and during Submission

Authors must ensure the information provided during the submission of a paper is authentic. Please go through the following checklist before submitting:

1. Authors must go through the complete author guideline and understand and *agree to Global Journals' ethics and code of conduct,* along with author responsibilities.
2. Authors must accept the privacy policy, terms, and conditions of Global Journals.
3. Ensure corresponding author's email address and postal address are accurate and reachable.
4. Manuscript to be submitted must include keywords, an abstract, a paper title, co-author(s') names and details (email address, name, phone number, and institution), figures and illustrations in vector format including appropriate captions, tables, including titles and footnotes, a conclusion, results, acknowledgments and references.
5. Authors should submit paper in a ZIP archive if any supplementary files are required along with the paper.
6. Proper permissions must be acquired for the use of any copyrighted material.
7. Manuscript submitted *must not have been submitted or published elsewhere* and all authors must be aware of the submission.

**Declaration of Conflicts of Interest**

It is required for authors to declare all financial, institutional, and personal relationships with other individuals and organizations that could influence (bias) their research.

## Policy on Plagiarism

Plagiarism is not acceptable in Global Journals submissions at all.

Plagiarized content will not be considered for publication. We reserve the right to inform authors' institutions about plagiarism detected either before or after publication. If plagiarism is identified, we will follow COPE guidelines:

Authors are solely responsible for all the plagiarism that is found. The author must not fabricate, falsify or plagiarize existing research data. The following, if copied, will be considered plagiarism:

- Words (language)
- Ideas
- Findings
- Writings
- Diagrams
- Graphs
- Illustrations
- Lectures

- Printed material
- Graphic representations
- Computer programs
- Electronic material
- Any other original work

## Authorship Policies

Global Journals follows the definition of authorship set up by the Open Association of Research Society, USA. According to its guidelines, authorship criteria must be based on:

1. Substantial contributions to the conception and acquisition of data, analysis, and interpretation of findings.
2. Drafting the paper and revising it critically regarding important academic content.
3. Final approval of the version of the paper to be published.

**Changes in Authorship**

The corresponding author should mention the name and complete details of all co-authors during submission and in manuscript. We support addition, rearrangement, manipulation, and deletions in authors list till the early view publication of the journal. We expect that corresponding author will notify all co-authors of submission. We follow COPE guidelines for changes in authorship.

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**Appealing Decisions**

Unless specified in the notification, the Editorial Board's decision on publication of the paper is final and cannot be appealed before making the major change in the manuscript.

**Acknowledgments**

Contributors to the research other than authors credited should be mentioned in Acknowledgments. The source of funding for the research can be included. Suppliers of resources may be mentioned along with their addresses.

**Declaration of funding sources**

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## Preparing your Manuscript

Authors can submit papers and articles in an acceptable file format: MS Word (doc, docx), LaTeX (.tex, .zip or .rar including all of your files), Adobe PDF (.pdf), rich text format (.rtf), simple text document (.txt), Open Document Text (.odt), and Apple Pages (.pages). Our professional layout editors will format the entire paper according to our official guidelines. This is one of the highlights of publishing with Global Journals—authors should not be concerned about the formatting of their paper. Global Journals accepts articles and manuscripts in every major language, be it Spanish, Chinese, Japanese, Portuguese, Russian, French, German, Dutch, Italian, Greek, or any other national language, but the title, subtitle, and abstract should be in English. This will facilitate indexing and the pre-peer review process.

The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.

***Manuscript Style Instruction (Optional)***

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11'", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

***Structure and Format of Manuscript***

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

a) A title which should be relevant to the theme of the paper.
b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
d) An introduction, giving fundamental background objectives.
e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
f) Results which should be presented concisely by well-designed tables and figures.
g) Suitable statistical data should also be given.
h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
j) There should be brief acknowledgments.
k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.



## Format Structure

***It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.***

All manuscripts submitted to Global Journals should include:

**Title**

The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

**Author details**

The full postal address of any related author(s) must be specified.

**Abstract**

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

**Keywords**

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, “What words would a source have to include to be truly valuable in a research paper?” Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

**Numerical Methods**

Numerical methods used should be transparent and, where appropriate, supported by references.

**Abbreviations**

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

**Formulas and equations**

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

**Tables, Figures, and Figure Legends**

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

**Figures**

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

## Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

## Tips for Writing a Good Quality Science Frontier Research Paper

Techniques for writing a good quality Science Frontier Research paper:

***1. Choosing the topic:*** In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

***2. Think like evaluators:*** If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

***3. Ask your guides:*** If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

***4. Use of computer is recommended:*** As you are doing research in the field of science frontier then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

***5. Use the internet for help:*** An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.



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***6. Bookmarks are useful:*** When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

***7. Revise what you wrote:*** When you write anything, always read it, summarize it, and then finalize it.

***8. Make every effort:*** Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

***9. Produce good diagrams of your own:*** Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

***10. Use proper verb tense:*** Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

***11. Pick a good study spot:*** Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

***12. Know what you know:*** Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

***13. Use good grammar:*** Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

***14. Arrangement of information:*** Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

***15. Never start at the last minute:*** Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

***16. Multitasking in research is not good:*** Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

***17. Never copy others' work:*** Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

***18. Go to seminars:*** Attend seminars if the topic is relevant to your research area. Utilize all your resources.

***19. Refresh your mind after intervals:*** Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

***20. Think technically:*** Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

***21. Adding unnecessary information:*** Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

***22. Report concluded results:*** Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

***23. Upon conclusion:*** Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

## Informal Guidelines of Research Paper Writing

***Key points to remember:***

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

**Final points:**

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

*The introduction:* This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

**The discussion section:**

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

**General style:**

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

**To make a paper clear:** Adhere to recommended page limits.



*Mistakes to avoid:*

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.
- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

**Title page:**

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

**Abstract:** This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

*Reason for writing the article—theory, overall issue, purpose.*

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

**Approach:**

- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

**Introduction:**

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

*The following approach can create a valuable beginning:*

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.

**Approach:**

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

**Procedures (methods and materials):**

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

**Materials:**

*Materials may be reported in part of a section or else they may be recognized along with your measures.*

**Methods:**

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

**Approach:**

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

**What to keep away from:**

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.



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**Results:**

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

**Content:**

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

**What to stay away from:**

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

**Approach:**

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

**Figures and tables:**

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

**Discussion:**

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Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

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- Recommendations for detailed papers will offer supplementary suggestions.

**Approach:**

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| ***References*** | Complete and correct format, well organized | Beside the point, Incomplete | Wrong format and structuring |

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