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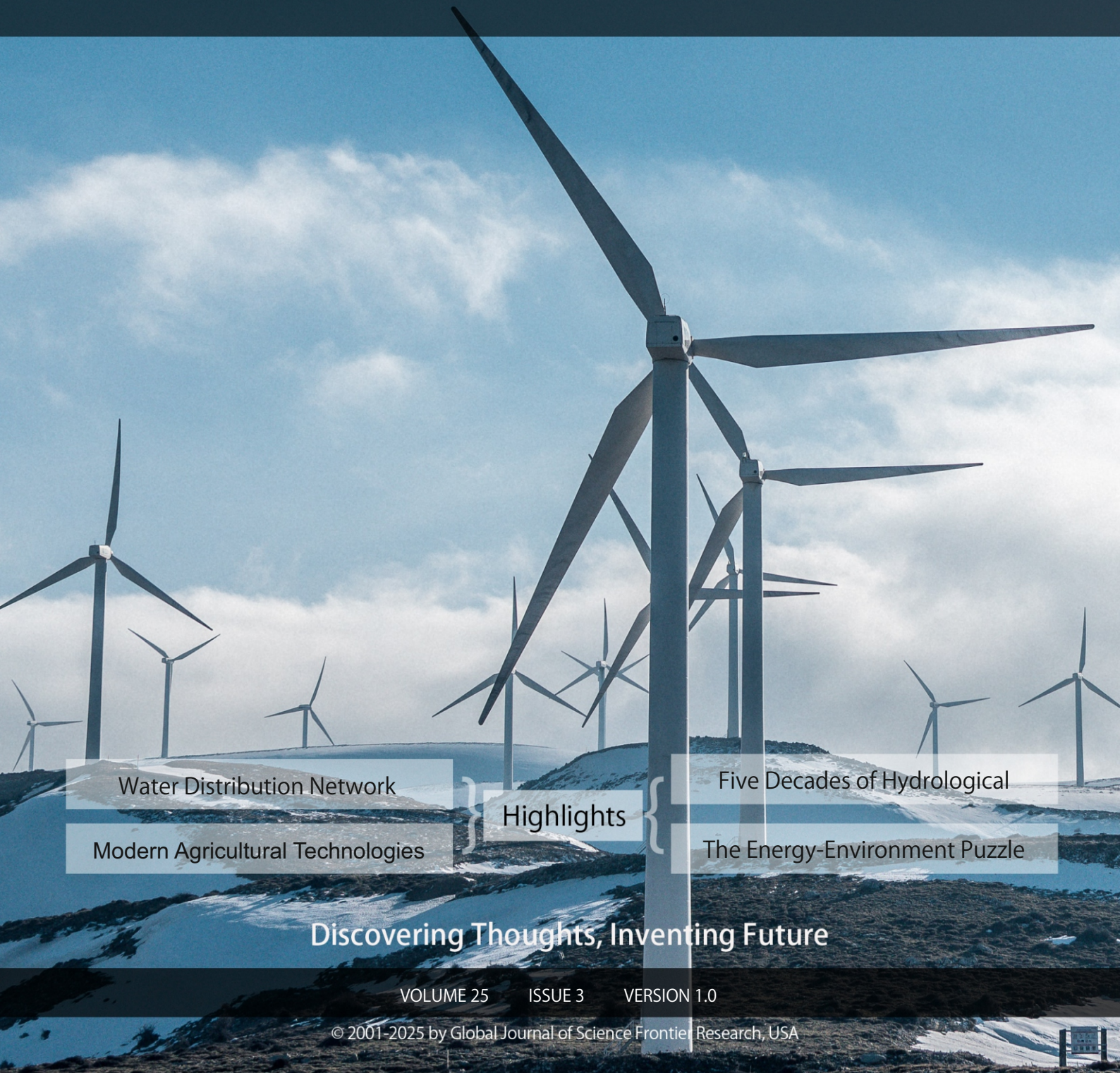

Water Distribution Network

Modern Agricultural Technologies

Highlights

Five Decades of Hydrological

The Energy-Environment Puzzle

Discovering Thoughts, Inventing Future

VOLUME 25 ISSUE 3 VERSION 1.0

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The Energy-Environment Puzzle – Reconciling Conflicting Goals

By Miguel Schloss

Abstract- Unpacking knotty performance issues.

We are in the midst of profoundly significant, changing and challenging times. By now it should be clear that various technologies (such as geothermal, renewables, green hydrogen) to decarbonize energy generation and overcome our global warming issues don't appear to have generated the much-needed global carbon emission reductions, despite heavy early investments in decarbonization to generate major savings in climate costs. Adding all up, the evidence strongly suggests that our progress doesn't seem to add much. Could it be that we are running faster, only to stay in place — and in the end despite all the alleged efforts, our progress is bound to fall short of the agreed decarbonization and global warming goals?

Clearly, developments so far, while helpful and promising, are just too limited to meet the mark. We need much faster or, better yet, more effective efforts to achieve tangible progress to meet the global demand at the pace the world is growing. To this end, we must become increasingly aware that we are seeking competing(if not conflicting) objectives between economic development, environmental improvement and affordability. This paper, which is aimed at explaining for skeptics and believers alike the need for a more "strategic" way of planning, to assess every step of the way the trade-offs we are making between the competing goals to archieve maximum impact with reasonably minimum or manageable input.

GJSFR-H Classification: *JEL Code: Q4, Q54*

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The Energy-Environment Puzzle – Reconciling Conflicting Goals

Miguel Schloss

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To do so, we must ourselves wean out of the tendency to emphasize process over actions and results. International gatherings too often become vanity shows to celebrate the issuance of more rules and regulations that in the end make the investment processes more complex and expensive, which deflect us from focusing on substantive actions and results on the ground. For too long, international for a have pressed for combating symptoms, not causes, focusing on processes, not results. A reorientation *from words to deeds* and closer attention on what we are achieving is now in order.

I. Introduction – Managing Transformations

Zhou Enlai, the Chinese statesman who served as the first Premier of the People's Republic of China, was once asked what he thought of the French Revolution. Popular lore has it that he responded that it was too early to tell.

Whether this is an accurate depiction of his thought or not, this cautious evaluation of such distant events could certainly apply to most revolutions, as he certainly must have learned -- as for that matter in any major change in structures and practices needed in recent developments on energy transition and environmental implications. A lot of assertions have been made on the role that growth of renewable sources of energy sources can play, the contamination that fossil fuels generate, and ultimately the type of energy mix one has to build –but, as in well-meaning revolutions, reality has shown to be more challenging to tame to produce the desired outcomes.

Conversely, limited attention seems to have been focused on the structural changes taking place in world economies and their impact on aggregate energy demand, affordability and reliability of different sources of energy. Ultimately, what matters is how all sources, put together, affect the trajectory of aggregate demand and their impact on carbon emissions and climate change.

After all, modern civilization, has acquired the power to prevent famines, contain epidemics, and mitigate natural disasters, such as hurricanes and even earthquakes. Energy, in its different forms is no different and ultimately is part of this evolution. In general, the acquisition of power and its different forms, the management among them, has enabled more effective management of risks, while simultaneously increasing the dangers that power systems may pose to themselves. For this reason, we must abandon both the naïve and populist views of imposing some arbitrary standards, and put aside our fantasies of infallibility, to commit ourselves to the hard and rather mundane work of building institutions and policies with strong self-correcting mechanisms to avoid misguided or ineffective efforts. This is perhaps the most important takeaway of development over the last decades, where the decarbonization efforts and the associated energy transition investments were ultimately aimed at reducing global warming that, for the time being at least, doesn't appear to be even near.

II. So, what is Happening?

Technology is rarely deterministic, and the same technology can be used in various ways. While it

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has always been a catalyst for major historical changes -- sometimes positive ones, often not so, but it invariably creating new developments – oftentimes revolutions included side effects alongside. For this reason alone, such developments need concurrent tracking to ensure timely and proper corrective actions if such changes start generating undesirable or insufficient impact.

This, of course, is more easily said than done. Oftentimes, technological developments and associated institutional changes are more than capable of promoting distorted worldviews, enabling egregious abuses of power. Such developments have tended to instigate single-minded militant and promotional views, which have repeatedly throughout history generated extreme circumstances, with their share of terrifying new witch hunts.

III. What is the Actual Record? – Projections vs. Outcomes

Broadly speaking, leaving fine points aside, here is a broad-brush record and outlook of global supply and demand for energy of the last ten years and how we are headed into the future.

An international outlook serves multiple purposes. First and foremost, it establishes the basis for long-term business planning of all actors concerned. In general, the energy industry is capital intensive and long term by nature. We thus need to understand what the world could look like in coming decades to plan and deploy capital wisely. Emerging markets alone (where the bulk of growing energy demand is taking place as a result of economic growth and urbanization) developing countries will need to spend an additional $1 trillion per year on climate-related goals by 2025 and around $2.4 trillion per year by 2030.

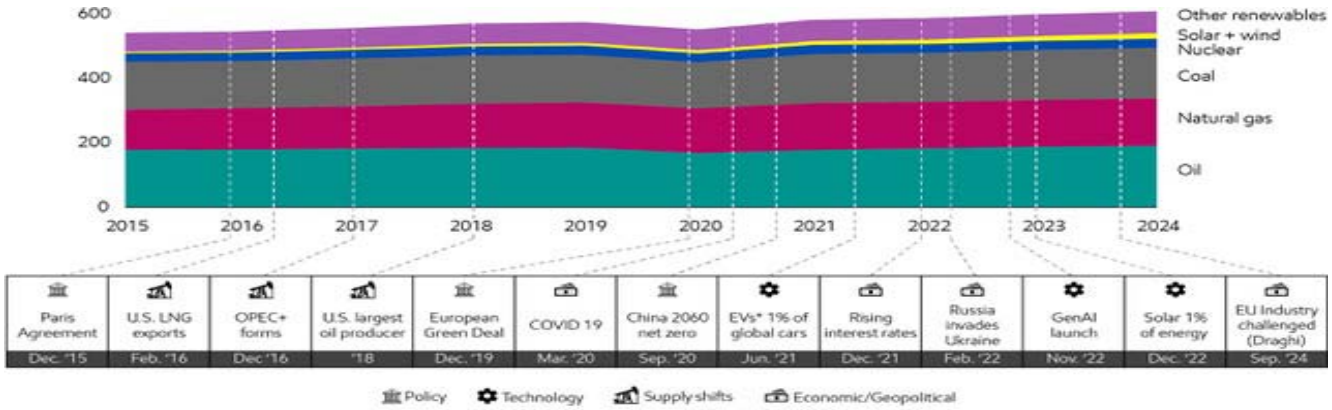
Yet the global outlook serves a broader purpose as well. Energy and products are inseparable from modern life. Access to affordable and reliable energy drives unprecedented economic progress and improved living standards. They also contribute to global emissions. A global outlook provides essential insights into the economic advantages and environmental considerations that play a part in the future of energy.

The projections at the heart of the outlook represent a most likely (not single-minded) view of the world in 2050. It is generally scientifically grounded, based on detailed analysis of a variety of data sources and long-term assessments of market fundamentals, economic trends, technology advancements, consumer behavior and climate-related public policy. It is not an endorsement of a particular outcome, nor is it advocating for what any single source hopes will happen.

There is uncertainty inherent in any future projection, and it is essential to constantly learn and improve our insights and models – and adjust and plan accordingly. Think about it; over the last 10 years we've seen the signing of the Paris Agreement for climate action, a global pandemic, Russia's invasion of Ukraine significantly altered global gas flows, the reemergence of the U.S. as an oil exporter, and huge growth (yet limited in overall terms) in deployment of renewable energy.

These are just a few examples, and yet as can be seen in the graph below, there hasn't been a year where there haven't been some significant macro development affecting energy development. Yet, through all of this, rising prosperity and energy demand have remained inextricably linked, and the global energy mix has mainly remained essentially unchanged.

Global energy mix has remained largely constant in a dynamic world (2015-24)



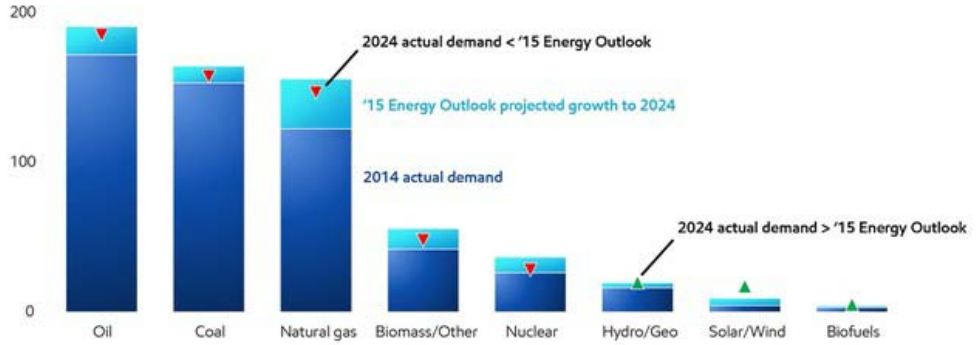
Sources: UNFCC, EIA, OPEC, EU Commission, EIA, US Federal Reserve, Grantham Institute

**EVs include Battery Electric and Plug-in hybrids – Quadrillion BTU.*

Looking back at outlooks prepared by important energy sector actors, like oil, gas or coal companies, or relevant research institutions, we can see that while projection weren't perfect, by and large they provided a sound basis for strategies and plans. Even so, these "look-backs" also highlighted the immense scale and

inertia of the energy system. Significant economic and geopolitical events had either near-term or localized impacts, but in the big scheme of events, only minor impact relative to the projections made ten years ago.

Energy trends over the past decade validate 2014 projections



Exxon Mobile (2015-2024 Energy Global Outlook)

Quadrillion BTU;

Low carbon includes Biomass, Biofuels, Nuclear, Hydro, Geothermal, Solar, and Wind.

Oil excludes biofuels.

Most striking of all is the marginal change in the energy mix over this decade, as traditional hydrocarbon sources (oil and coal) declined by just 1 percentage point each, while solar and wind grow by 2 percentage points, though from a very low basis to reach 3 % of total sources and natural gas 1 percentage point increased to reach close to a quarter of total (though contributing a lower emission footprint than traditional hydrocarbons):

Decarbonized energy sources increased marginally in energy mix in past decade

	2014 (actual)	2024 share	
		'15 Energy Outlook projection	Actual
Oil	31%	30%	30%
Coal	27%	26%	26%
Natural gas	23%	24%	24%
Biomass / Other	9%	9%	8% ↓
Nuclear	5%	6%	5% ↓
Hydro / Geo	3%	3%	3%
Solar / Wind	1%	1%	3% ↑
Biofuels	1%	1%	1%
*Low carbon	19%	20%	20%

Oil excludes biofuels

Digging deeper into this look-back analysis, there are several insights that inform our current Outlook and highlight some of the challenges society faces as it works to lower emissions while providing affordable, reliable energy that underpins economic growth. In 2024, for instance, global energy demand was ~4% lower than projected in the 2015 Outlook. Some of this difference is related to the pause in growth during the pandemic, but a bigger driver was slower economic development in Latin America and Sub-Saharan Africa. The 2015 Outlook had assumed rising prosperity in these regions, but income per capita was stagnant over the past ten years. These trends reinforce that rising prosperity and energy demand are inextricably linked.

Oil demand (excluding biofuels) was 2% lower than projected, with the shortfall again due to slower economic development in emerging economies. Oil demand in high income OECD countries and China

grew stronger than projected a decade ago, led by higher demand for transportation fuels.

Natural gas demand grew the most over the last decade, but 2024 demand was 6% lower than 2015 Outlook projection. The developing world, excluding China, contributed, as did Europe, where the loss of pipeline gas and higher prices following Russia's invasion drove Europe's gas demand nearly 20% below 2015 Outlook projections. Low-cost domestic gas resources in the United States and the Middle East drove stronger demand growth than the 2015 Outlook projection.

One can also see that solar and wind grew nearly twice as much as projected in the 2015 Outlook projections, with over half of the difference occurring in China. The combination of policy incentives and technology cost declines encouraged faster deployment. But even with the more rapid growth, solar and wind still only made up ~3% of the world's energy mix in 2024. This illustrates the massive scale of the global energy system.

Looking more broadly at low carbon sources, including nuclear and renewables, we see low carbon sources gained 1% share over the past decade, aligned with the 2015 Outlook projection. The faster solar and wind growth was offset by a significant decline in nuclear energy, led by reactor shutdowns in Europe.

Given the uncertainty inherent in any projection, a range of sensitivities and scenarios – including those we view as remote – must be included to help inform strategic thinking. No future projection could exactly predict every new government policy, its effectiveness, or its unintended consequences. Similarly, the pace of technology advancements and extent of public support for more expensive, lower-emission solutions can influence how quickly or cost-effectively different energy pathways might develop.

All in all, the Global Outlook is made publicly available because it makes an important contribution to a variety of policy discussions – about energy, about economic development, and about the environment. By offering a clear-eyed, thoughtful view, the Outlook can enhance those discussions and – hopefully – lead to better decisions and policy outcomes.

IV. Key Takeaways when Renewables Soar – Just as Fossil Fuels do...

In a year when average air temperatures consistently breached the 1.5°C warming threshold, global CO_2-equivalent emissions from energy rose by 1%, marking yet another record, the fourth in as many years. Here are key factors explaining this overall outcome:

- Wind and solar energy alone expanded by an impressive 16% in 2024, nine times faster than total energy demand. China was responsible for 57% of new additions, with solar almost doubling in just two years (from an admittedly low level). Yet this growth did not fully counterbalance rising demand elsewhere, with total fossil fuel use growing by just over 1%, highlighting a transition defined as much by disorder as by progress. In part, the results could be aligned with a better understanding of business conditions across countries to develop better energy investment responses to the different economic prospects among various jurisdictions.
- Crude oil demand in OECD countries remained flat, following a slight decline in the previous year. In contrast, non-OECD countries, where much of the world's energy demand growth is concentrated and fossil fuels continue to play a dominant role, saw oil demand rise by 1%. Notably, Chinese crude oil demand fell in 2024 by 1.2%, indicating that 2023 may have reached a peak. Elsewhere, global natural gas demand rebounded, rising by 2.5% as gas markets rebalanced after the 2023 slump. India's demand for coal rose 4% in 2024 and now equals that of the CIS, Southern and Central America, North America, and Europe combined.
- These trends underscore a stark truth: while renewable energy is scaling faster than ever, global demand is rising even faster. All-time *records were reached across ALL forms of energy (coal, oil, gas, renewables, hydro and nuclear).* Rather than replacing fossil fuels, renewables are adding (and till marginally) to the overall energy mix. This pattern, marked by simultaneous growth in clean and conventional energy illustrates the structural, economic, and geopolitical barriers to achieving a truly coordinated global energy transition.
- This year's data reflects a complex picture of the global energy transition. Electrification is accelerating, particularly across developing economies where access to modern energy is expanding rapidly. However, the pace of renewable deployment continues to be outstripped by overall demand growth, 60% of which was met by fossil fuels. The result is a fourth consecutive year of record emissions, highlighting the structural challenges in aligning global energy consumption with climate goals.
- All primary energy sources, including nuclear and hydro, hit record consumption levels (for the first time since 2006), a reflection of surging global demand. No country has shaped this outcome more than China. Its rapid expansion of renewable capacity, alongside continued reliance on coal, gas, and oil, is driving global energy trends. The scale and direction of China's energy choices will be pivotal in determining whether the world can deliver a secure, affordable, and low-carbon energy future.

- Record-high GHG emissions and soaring temperatures in 2024 are a serious wake-up call. We have the strategies, technologies, and know-how to deliver the energy transition with potentially an integrated, secure, and people-centred approach. Now, we must move from action, at scale and at speed. With greater attention to investments in energy storage and transmission, there is potential to overcome the lower load factor and heavy weather- and location-reliance of renewables, thereby levelling their competitiveness with traditional sources of energy.
- Several countries have came forth with new climate plans and announcements at the UN High-Level Event on Climate Action. These lay out emissions targets through 2035, as waypoint on the path to net zero by mid-century. Yet, despite the commitments made many times in the past, even with the more ambitious goals compared to previous climate commitments, the targets announced to date, the trajectory and results fall far short of what's needed to stay within critical warming thresholds. By 2035, the world needs to cut 31.2 gigatons of emissions to stay on track for 1.5 degrees C, or 20.2 Gt for 2 degrees. By now, more than new goals, what is needed concrete strategies, action programs, proper economic and sector policies that provide the necessary conditions and incentive structures, so that productive sectors undertake the necessary investments to achieve this order of change and necessary resilience.
- Globally, we are still not at the pace required, as energy demand continues to rise. This year's data highlights how Europe has been facing a reality check, with rising effective interest rates and supply chain costs slowing progress on renewables, at the same time China and other emerging markets continue to drive growth at scale. What's emerging is not a uniform transition, but a need to address a highly diverse set of local conditions.

V. Where do we go from here – with Fossil Fuels at the Heart of a Burning Issue?

Rather than aiming to achieve artificial aggregate goals, and build more, costly and time-consuming oversight mechanisms, emphasis must shift towards practical strategies built for resilience, recognizing that energy security and affordability remain central concerns -- competing and in need to be reconciled with climate action.

In a world with greater volatilities and structural changes, policy-makers and business leaders must increasingly seek to navigate an uneven energy transition, one shaped by diverging regional trends, infrastructure constraints, policy fragmentation and institutional capabilities. Key questions to be henceforth considered in the investment process by business and policy leaders may have to include:

- What does it mean for a strategy when the energy mix is shifting, but not in the way many expected, with gas, oil and coal continuing to play significant roles?, and thus, how we can tilt incentives towards lower emitting hydrocarbons – i.e., towards gas and disincentivize coal?
- How does one respond when electricity demand surges, renewables can't keep up everywhere, and energy systems are already straining under the pressure?
- Are strategies focused where progress is happening –not just where it's expected?, and are we focusing on institutional and other constraints to open up investment opportunities, risk intermediation arrangements in other forms of energy not yet as widely in use, such as geothermal, green hydrogen, etc.?
- How does one prepare for a market where trade flows are shifting, policy signals are mixed, and volatility is here to stay?
- Can one's business thrive in a world where complexity, fragmentation, and disruption are now the norm?. If so, how can we shift attention from processes, target-settings and other intermediary concerns to outcome, and results.

With world primary energy demand projected to increase by more than half over the next 25 years, we are facing the formidable twin challenges of finding secure and affordable supplies of energy while addressing the environmental impacts of that increased consumption. The geographic dislocation between the sources of energy supply and demand and the heightened geopolitical risk in some of the traditional energy-supplying regions is also encouraging consuming nations to cast their nets wider for alternative supplies of energy. The US, the world's largest consumer of energy, and China and India, the fastest-growing consumers, are all characterised by relatively low or declining oil and gas reserves. They all possess substantial reserves of coal… but coal is the most carbon-intensive of the fossil fuels.

The are important drawbacks with the current path and constraints, but there important efforts among companies leading the field in green-technology development. This is bound to take time, and the fact remains that most electricity is generated from fossil fuels and until it can be produced on a huge scale from economically feasible alternatives including renewable resources, the production, storage and transportation of hydrogen and other such sources on a commercial

scale affect the climate no less than the refining of crude oil.

So, in the 21st century, the world faces twin energy-related threats: that of not having adequate and secure supplies of energy at affordable prices and that of environmental harm caused by consuming too much energy in inappropriate ways.

A solution to either of these threats is relatively straight forward; however, a solution to both simultaneously is one of the great challenges of our times. With global energy demand expected to rise by 53% over the next 30 years, and fossil fuels accounting for 83%of the overall increase, simply calling for a cut in consumption is not a sufficient solution to the challenges we face.

Accordingly, in the short term, fossil fuels, including coal have an important role to play in enhancing energy security and fuelling both economic growth and poverty alleviation globally. Looking towards the medium term, however, greater efforts must shift towards: (i) technological development, including deployment of enhanced information technology for more rational use of scarce energy sources; and (ii) trimming energy demand though proper pricing (and taxation) of carbon emissions, to reflect the cost of environmental externalities in energy sources, thereby dampening energy demand to help reduce above-mentioned gap in the energy scenery. There are some 50 countries that have such initiatives in different (though mostly early) stages of development.

In the end, a more determined effort is needed to change the incentive structure and move such initiatives into implementation. This will be indispensable to narrow the gap to embed these costs into consumer behavior, and eventually meeting the global emission and climate change objectives.

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Five Decades of Hydrological, Vegetation and Biodiversity Responses to Climate Change in a Southwestern Australian Jarrah (*Eucalyptus marginata*) forest (1972-2024)

By Frank Batini
Murdoch University

Summary- Water is a key driver for many ecosystem processes. The integration of various sets of data for the 2000 ha 31 Mile Brook catchment allows an holistic evaluation of the responses by this ecosystem to substantial changes in hydrology. Excellent baselines for hydrology and vegetation are available from 1972.

From the late 1960's there has been a major reduction in rainfall in the South-West of Western Australia and an even greater decline in stream flow. Modelling simulations closely matched the observed drying trends in stream flow, flow days and groundwater depth. The model was then used to estimate the impact of thinning treatments on these values. Between 2004 and 2010, the estimated evapotranspiration matched the average rainfall and soil moisture storage fell.

Keywords: *climate change, ecosystem health, catchment water balance, modelling.*

GJSFR-H Classification: *LCC Code: QC981.8.C5*

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Estimates of Leaf Area (LAI) show steady canopy growth after good rainfall years (to 1.5) and then a substantial decline, as a result of the very dry 2010 winter. Crown scorch and some tree deaths on shallow soils were observed in autumn 2011 and again in 2024. Detailed mapping of species composition in 1972 and remapping in 2012 showed only a slight xeric shift. In 2024, the tree stratum was healthy, but small changes in composition were observed, some as the result of a prescribed burn, others due to drought.

Aquatic biodiversity between 1984 and 2010 reveal shifts in faunal assemblages, species richness and abundance, but only for a few species that have longer life cycles. A range of terrestrial biota show little change, as the understorey vegetation on which they depend for food and shelter is still healthy.

So far, this ecosystem has shown remarkable resilience to a changing climate. Modelling suggests that thinning the tree stratum to a basal area of 14 would benefit soil moisture and increase stream flow. Thinning for ecosystem health is now approved in the Forest Management Plan (DBCA 2024). Recommendations for ongoing management and research are made.

Keywords: climate change, ecosystem health, catchment water balance, modelling.

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I. Introduction

The jarrah (*Eucalyptus marginata*) forest now covers about two million hectares, located in the extreme south-west of Western Australia. This region has a "Mediterranean-type" climate with hot, dry summers and cooler, wet winters. Rain is brought by a series of low and high pressure systems that travel along a band of latitude know as the "roaring forties". During winter these move closer to the equator and bring the rain.

Every summer there is potential for severe bushfires to occur. This risk is mitigated by a program of prescribed burning that aims to cover between 150000 and 200000 hectares annually. This program aims to keep 45% of the forest with a fuel load that is less than six years old. Low fuels are much easier and safer to control with ground attack crews.

Jarrah trees may live some 350 years and are very resistant to fire, with multiple epicormic shoots on the stem and branches which are protected by a thick bark as well as a lignotuberous seedling stage (Abbott and Loneragan 1986).

The predominant soil is an ancient, deeply weathered (30 meters) and infertile lateritic profile. Where streams have cut into the underlying granite the soils are slightly more fertile, comprising of red and yellow earths with lateritic gravel (Churchward and Batini 1975).

Remarkably, this infertile site carries a magnificent *Eucalyp*t forest over 30 meters in height, predominantly of jarrah *(E.marginata*), a beautiful red-colored timber which is highly versatile in use and resistant to termites. The forest has high carbon storage (up to 600 m3/ha) but low productivity (<2 m3/ha). Timber production commenced soon after settlement by Europeans in 1829 and large quantities were harvested for local use and export, especially between 1880 and 1970. Commercial timber harvesting ceased in 2023, the Government claiming concerns about Climate Change as the reason.

Substantial reductions in rainfall in the south-west forests have been linked by academics, the media and environmental groups to rising levels of carbon

dioxide in the atmosphere (Batini 2025). The Forest Management Plan (2024-2033) identifies that Climate Change "will be a persistent, escalating stressor on all ecosystems in the planning area". Detailed and expensive monitoring of ecosystem health is now being implemented. However evaluating the effects of a changing climate on a forested ecosystem will require decades of data collection before any significant trends emerge. An alternative approach adopted in this paper is to compare the current situation with data collected in the past.

The catchment of the 2000 ha 31 Mile Brook allows such a comparison, since excellent baseline data for vegetation and stream flow are available from 1972. The Brook is located 50 kms south-east of Perth and a short distance downstream, at Canning dam, the rainfall average in the 1970's was 1290 mm. In 2006 the gauging and rainfall stations were re-opened and an extensive program of research into the effects of changing climate on hydrology, vegetation health and biodiversity commenced. The premise was that the effects would be negative in direction and significant in scale.

Jarrah is the dominant eucalypt, interspersed with marri (*Corymbia calophylla*) on more fertile soils and blackbutt *(E.patens*) and bullich (*E. megacarpa*) growing on water-gaining sites. A detailed description of the vegetation complexes is provided by Havel (1975b). This is a regrowth forest, basal area 25m2/ha, that has been selectively harvested for timber and then regenerated on at least three occasions.

II. Hydrology

Rainfall from 1880 at Jarrahdale, 15 kms away, show a cyclical dry-wet-dry cycle from 1880-1914, 1915-1965 and1965 to present (1100 mm, 1251 mm and 1054 mm, Fig 1). Very high rainfall years were: 1915, 1917, 1945, 1946, 1963, 1964 and 1967. These replenished the groundwater and filled the dams,

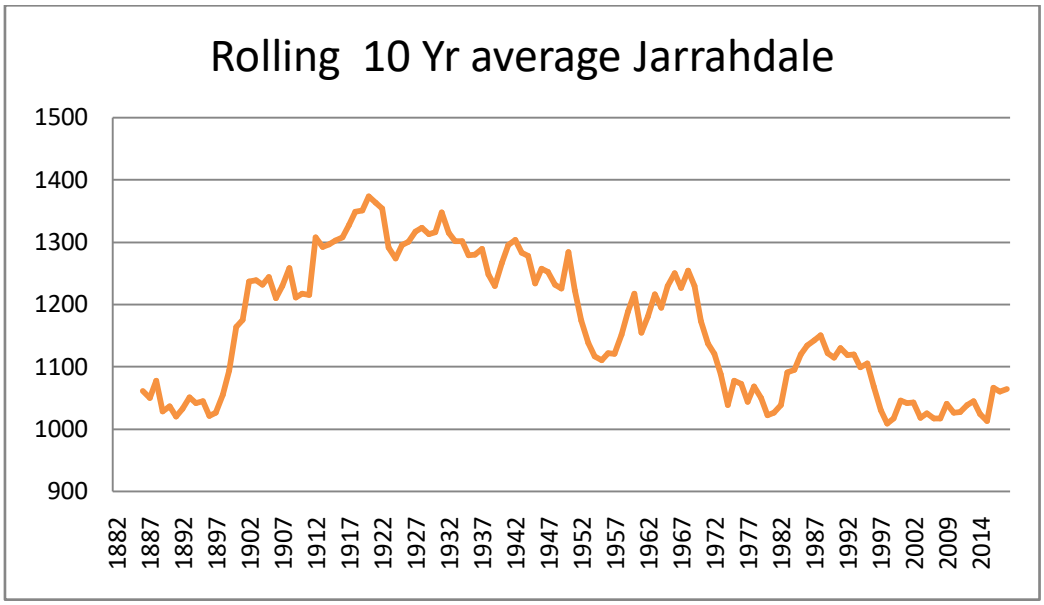

Figure 1: Jarrahdale Rainfall (32.3342 S, 116.0755 E, 240m ASL). Bureau of Meteorology rainfall data at Jarrahdale since 1882. (Michael J Freeman)

At 31 Mile Brook the flows are highly variable, ranging from 236 mm in the 1970s to 96mm in 2009 after three good years of rainfall, to only 4mm in the 2010 drought year (Silberstein *et al* 2011).

The forest has continued to transpire drawing on soil-water and groundwater reserves. This has led to a major decline in groundwater levels since the 1970s. Simulations by Croton *et al* (2012) show a fall of several meters (Fig 2). Eventually the groundwater became disconnected with the stream leading to a marked reduction in both winter discharge and summer baseflow.

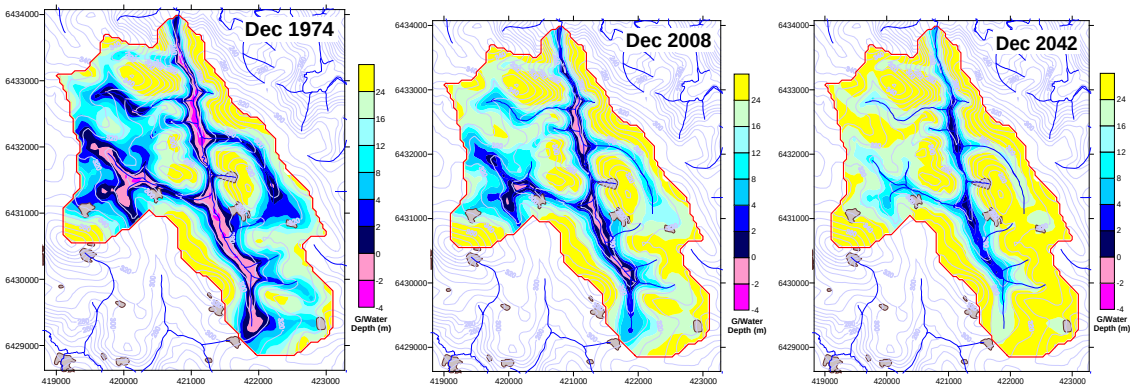

Figure 2: Simulated depth to groundwater (Croton *et al* 2011)

III. Forest Cover

Trends in forest canopy cover between 1989 and 2007 were analysed by Landsat imagery (Wallace *et al* 2009). The western, higher rainfall zone was either a stable or increased cover. In contrast, the drier, eastern forests showed a widespread reduction in canopy cover.

CSIRO also measured a Landsat derived leaf area index in 31 Mile Brook between 2004 and 2011 (Silberstein *et al* 2011). Data show a gradual increase in cover from 2007 to 2009 (by 70 percent, to LAI of 1.5) after three years of good rainfall. Following the drought in 2010, cover fell by 21 percent, indicating a rapid capacity to adjust to prevailing conditions.

IV. Catchment Modelling

The catchment model (WEC-C) was specifically designed for the jarrah forest (Croton *et al* 2011). Modelling showed that annual stream flow in 31 Mile Brook was correlated (0.91) to the total inflow for all catchments that comprise the Integrated Water Supply System. This Brook can be considered as being representative of catchments in the higher rainfall areas.

Comparisons of observed and modelled results were made between 1986 and 2011. There was a good match of data and the model was able to follow the drying trend in both stream flow (from 200 mm to 50 mm) and in flow days (from 350 to 170 days). The decrease in soil water storage was calculated as 1100mm. In the early 1970's extensive areas of the valley floor had positive heads above the soil surface but by 2010 the groundwater contact with the surface was limited (Fig 2).

CSIRO used TOPOG and canopy data based on an index derived from Landsat (Silberstein *et al* 2011). This model also produced a good match between observed and predicted results for stream flow, groundwater and soil storage. The model was used to estimate the proportion of reduction in flow due to lower rainfall (about 2/3) and to increased forest cover (about 1/3).

V. Simulations of Thinning Treatments (WEC-C)

Simulations: Thinning treatments ranging from Leaf area values of 0.4, 0.6, 0.8, 1.0 and 1.25 (the untreated control) were used to understand the management regimes required to recover groundwater and stream flow (Croton *et al* 2011). An annual rainfall of 958mm (the average rainfall for the years 2001 to 2010) was then applied in sequence for five times, to 2060. Sensitivity analyses using different rainfall levels and sequences are possible but were not done.

Results: The untreated scenario caused the groundwater to become completely disconnected from the stream zone. The resulting flows were calculated as 40 mm in 2020, decreasing to 28 mm in 2060. As a comparison the catchment yielded an average of 236mm in the 1970s and 74 mm from 2001-2010.

If a thinning treatment to a leaf area of 0.8 (basal area 14) were done, stream flow would be maintained at 75 mm, flow-days would increase over the control by 90 days and soil storage by 1250 mm. Thinning to a lower LAI of 0.4 or 0.6 would increase stream flow and storage even further.

Discussion: Thinning of over-stocked stands increases the growth rate and health of the retained trees by reducing competition for water and nutrients. Interception is reduced, soil moisture increased, the overall evapotranspiration is lowered but evaporation from bare soil is raised. If the area that is thinned is large, the watertable will rise and stream flow increase. The results obtained in the modeling are consistent with these well-established hydrological processes.

VI. Catchment Water Balance

Macfarlane *et al* (2011) reported on their water balance studies from 2004-2010, and this work is also included in Silberstein *et al* (2011). The annual interception was calculated as 13%, the over storey transpiration as 45% and the evaporation from understorey and bare ground as 42%, totaling 948 mm.

During this period, the mean annual rainfall was 947 mm, which included two drought years, 748 mm in 2006 and 524 mm in 2010. The catchment moisture storage decreased by 63 mm on average, or 441 mm in total. Mean runoff was 61 mm, about six percent of rainfall, mostly coming out of storage.

Macfarlane also compared the water use of large trees versus smaller trees. Though sap-flow rates were similar, the water use in larger trees was about half that of smaller trees. This is due to the much larger sapwood area in smaller trees (for any given basal area), as well as a higher crown cover and leaf area. In regrowth forest the evapotranspiration from the overstorey /unit Leaf Area Index (LAI) was about 310 mm.

VII. Environmental Values

The observed changes in rainfall, water tables, soil moisture storage and stream flow from 1880 to 2024 would be expected to have significant effects on forest health and biodiversity.

Drought In May 2011 there was crown scorch and some drought deaths associated with shallow soils adjacent to exposures of country rock. There was abundant excision of leaves and even large branches, up to 3cm in diameter. Marri was more resistant to drought than jarrah, and there was minimal effect on under storey species. Scorch was again observed in 2024.

Waterlogging Jarrah trees are susceptible to both water logging and *Phytophthora* disease (Davison and Tay 1987), whereas marri, black butt and bullich are tolerant to infection and thrive on wetter sites. Excessive rainfall between 1915 and 1965, (Fig 1), the associated water logging (Fig 2), combined with *Phytophthora* disease impacted about 12% of the catchment area (Havel 1975 b). Sites where jarrah was killed were then colonized by the other three eucalypt species. Water logging has had a much greater environmental impact on both jarrah and under storey species than the drought deaths observed since 2011.

Vegetation Comprehensive mapping of the tree statum, of shrub species in the understorey, of site-vegetation complexes, soils, dieback, altitude, slope and rock surfaces was published in 1975 by Havel, with field work carried out some years earlier. Five hundred vegetation plots were set up on a 400m x 100m grid and on each plot of 40m x 40 m all trees greater than 7.5 cm at breast height were measured. Within each larger plot, sixteen quadrats each of one square meter were selected and the cover contribution of each perennial species was estimated.

Based on previous studies, 55 species were selected as good indicators of site. For field mapping the vegetation continuum was split into 14 segments, based on the indicator species and the underlying environmental conditions. These were then mapped using both the field data and aerial photos. This extensive study provides an excellent baseline.

Forty years later, 480 of the sites were used to re-measure the tree stratum, the shrub cover and to re-map the site-vegetation complexes (Mattiske 2012). Recorded in this survey were 242 vascular plant taxa, from 124 genera and 48 families.

When the two maps were overlaid, localised shifts in classification were noted in some heads of gullies and adjacent to rock surfaces. Overall there was excellent agreement between the two maps:

Type	Location	Area 1972	Area 2012	Percent
S and P	Crests/slopes	Havel 1477 ha	Mattiske 1490 ha	79
C,D,W,Q	Water-gaining	Havel 350 ha	Mattiske 343 ha	18
R and G	Exposed rock	Havel 58 ha	Mattiske 56 ha	3

A comparison was also made on abundance for both tree and under storey species. Some species that prefer moister soil conditions, for example black butt, bullich and the shrub *Hypocalymna angustifolium*, were slightly less abundant in 2012, indicating a small xeric shift. Scorch and some tree deaths were recorded on shallow soils, especially near exposures of rock. There was no widespread collapse of streamside vegetation.

Road reconnaissance by me in 2021 and 2024 along several tracks confirmed that the both the tree and understorey strata in 31 Mile Brook catchment were still healthy. The site had been prescribed burnt in 2017 and some patch death of bullich were seen where the heat was more intense. In these patches the native legume albizia *(Paraserianthes lophantha*) had regenerated vigorously. This short-lived species will eventually be replaced by swamp peppermint or tea tree *(Taxandia linearifolia*, previously *Agonis linerifolia*).

Terrestrial biodiversity The dense streamside vegetation provides excellent cover, protection from predation and food sources for a range of native marsupials, mammals and birds, including the endangered red-eared firetail (*Emblema oculata*), golden whistler(*Pachycephala pectoralis fuliginosa*) and white-breasted robin(*Eopsaltria georgiana)* (Johnstone and Kirkby 2009) and also the quokka (*Setonyx brachyurus*), quenda(*Isoodon obesulus*), chuditch (*Dasyurus geoffroii*) and rakali(*Hydromys chrysogaster*) (Dundas *et al* 2011).

In addition seed-eating birds such as the forest red-tailed black cockatoo (*Calyptorhynchus banksii naso*)and the bronzewing pigeon (*Phaps chaleoptera*) require regular access to water. From 2010 to 2011 a viable population of the mainland quokka was being studied by S. Dundas using monthly trapping and fixed cameras.

Swamp systems at the terminal end of tributaries (gully heads) are the most likely places where changes in occupancy by native species may occur as the result of loss of habitat. A key feature is the maintenance of the quality of this habitat, with a mosaic of fire ages preferred, so as to provide both adequate cover and food source. As the observed shifts in streamside understorey vegetation have been minor, the impact on key terrestrial fauna and birds to date is considered as minimal.

Aquatic biodiversity Comparisons between 1984 and 2010 show that similarity in assemblages has recently shifted by up to 10 percent as the stream has become increasingly seasonal and longer lifecycles cannot be completed. Macroinvertebrates play a vital role in freshwater food webs (Davies and Storey 2012).

The distribution of freshwater species will become increasingly restricted, including species such as Gondwanic dragonflies, stoneflies, freshwater snail, crustaceans and mussels. Breeding habitat for frogs and native fish will also be reduced.

VIII. Discussion

Water is a key driver for many ecosystem processes. The integration of various sets of discrete data for the 31 Mile Brook catchment allows an holistic evaluation of this ecosystem's response to changes in forest structure as well as a major reduction in rainfall over the past 50 years. As a consequence groundwater levels have fallen, the soil storage has decreased and stream flow is markedly lower. It is estimated that about 65 percent of the change is due to reduced rainfall and that 35 percent to higher transpiration rates in smaller trees.

Vegetation Dynamics: Crown cover has shown an ability to respond quickly and substantially to annual rainfall, increasing in wet years and shedding leaves and larger branches during drought. Despite the overall reduction in rainfall, the long-term trend in this catchment has been to increase its crown cover, the opposite of what was expected. This may be due, in part, to enhanced photosynthesis as a result of increased levels of carbon dioxide in the atmosphere.

Hydrology: The forest is transpiring or evaporating all of each year's rainfall, drawing down on its moisture store, and it is unclear for how long this can continue. The water loss from understorey and bare ground is a significant component of the total loss. Regular prescribed burning is practiced on a 10-12 year cycle. This reduces evapo-transpiration from the understorey but increases evaporation from bare ground. Thinning of the tree stratum requires regular control of coppice from the cut stumps.

Ecological effects: The observed changes to rainfall, water tables, soil moisture storage and stream flow over such a long period of time would be expected to have significant effects on forest health and biodiversity. Only few tree deaths have been observed on shallower soils and occasionally on moister sites. While the death of some trees may be regrettable, the vegetation adjacent to stream lines has not collapsed, but has shown a small xeric shift in some gully-head sites. The dense understorey on which mammals and birds depend is still healthy and any impacts to fauna are considered as minor. A few aquatic species with longer life cycles are occasionally unable to reproduce.

a) Management Implications

Resilience: Since 1880, the jarrah forest has shown a high level of resilience and any tree deaths are natural changes as the result of multi-decadal cycles that may be wetter or drier than average (Batini 2025), The current dry period in certainly not "unprecedented". Rainfall records (Fig 1) and tree ring studies of karri (*E. diversicolor*) and *Callitris* show that the 19th Century (when carbon dioxide levels were low) was much drier than the present and that the 20th Century (as carbon dioxide levels were rising) was the wettest on record (Oliver 2023, O'Donnell *et al* 2021).

Bushfire management: A high intensity bushfire will have a much greater negative and longer-term impact on vegetation, water quality and fauna (Figure 3). Regular prescribed burning that results in patchy burns of varying intensity, followed up by baiting for predator control is recommended.

Figure 3: A Bullich wetland near Willowdale devastated by the Yarloop bushfire. Trees, understorey and fauna species were killed over thousands of hectares. Habitat was destroyed for several years (F Batini, March 2016)

Thinning for ecosystem health: The modelling carried out by Croton Consulting matched observed data and gives confidence that the predictions made about management options would be reasonably accurate. These showed that regular thinning to a leaf area of 0.8 (basal area of 14) together with coppice control could maintain stream flows at the 2000-2010 levels, which is encouraging. However thinning is expensive and will only be done on priority areas. The bulk of the forest will need to cope with a changing climate without silvicultural intervention. The Government's Forest Management Plan 2024-2033 takes a pessimistic view of the effects of Climate Change on ecosystem health and the decision to end timber harvesting in 2023 was based on ideology and politics, not science.

Relevance for Mediterranean ecosystems : Since the jarrah forest soils and vegetation are unique, this study probably has little that is directly relevant to either native forests or introduced Eucalypt plantations elsewhere. The study does show the importance of using past data where these are available. I have found that younger researchers tend to avoid this approach, and prefer to establish their own, new trials. The tree ring studies have proved valuable. These show that most "unprecedented" weather events (drought, flood and fire) have occurred many times before… and the ecosystem has survived.

Recommendation: The 31 Mile Brook should be kept as an untreated catchment so as to build on this long-term study. The gauging and rainfall stations should be reopened, the boreholes re-measured, camera traps should check for the presence of the mainland quokka and vegetation plots in gully head sites should be measured to see if the slight drying trend observed in 2012 is continuing. The cost would be modest and the data updated to 2025 would be extremely valuable. There is no other forested catchment in Western Australia that has been monitored so thoroughly, over such a long time and during a period of major changes in hydrology. These recommendations have been passed on to the relevant Government Agency on several occasions. They were ignored, in favor of establishing new studies elsewhere.

Acknowlegements

The Water Corporation, Forest Products Commission, Forests Department, Bauxite Hydrology Committee, Premier's Water Research Foundation and the Bushfire Front have all provided support, funding and access to these studies. Mr Keith Barrett, formerly a Senior Manager at the Water Corporation instigated the re-opening of the gauging station and encouraged this research and Dr J J Havel and Mr R Edmiston established the original baseline vegetation plots in the 1970's. Michael J Freeman provided Figure 1.

Author's Note

My involvement in these studies was as a consultant on forest management to the Water Corporation. I sourced funding for some of these studies from the Water Corporation and the Forest Products Commission and then liaised with the researchers over several years. When funding ceased in 2012 the gauging station was closed and all research ceased. I continued to visit the catchment every few years to observe change, As none of the research in 31 Mile Brook has been published in peer-reviewed journals, I am concerned that, with deaths, retirements and Departmental restructures these valuable data may be misplaced and forgotten. While each report has value, it only tells part of the story. I thought it highly desirable to summarize the various reports into one document.
There are no conflicts of interest.

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Monitoring Losses in the Water Distribution Network in the Metropolitan Region of Aracaju/SE in DMC's

By Wendell Valença Bittencourt de Jesus, Marcos Luciano Alves Barroso, Leandro Barros de Santana, José Franco de Azevedo & Zacarias Caetano Vieira

Abstract- Real losses are inevitable in water distribution; however, efficient network management can lead to minimum acceptable values. The occurrence of leaks indicates a lack of maintenance of the pipelines, inadequate installations, and large variations in pressure and flow in the network. Thus, the study aims to compare data from Measurement and Control Districts, DMCs (32 and 33), which are part of the water distribution network of the Aracaju Metropolitan Region, with regional and national data, with the perspective of identifying opportunities for improvement that aim to reduce loss rates. The Water Loss Reports of the Sergipe Sanitation Company (DESO) were utilized, adopting seven parameters that were examined in the period from 2017 to 2022, where we sought to identify trends and significant correlations. In which the DMC 32 correlation matrix demonstrated high agreement, particularly showing 66.66%, which indicates a strong correlation between the parameters.

Palavra-chave: *água, DMC, perdas, saneamento.*

GJSFR-H Classification: *LCC: TD223*

Strictly as per the compliance and regulations of:

Monitoring Losses in the Water Distribution Network in the Metropolitan Region of Aracaju/SE in DMC's

Monitoramento De Perdas Na Rede De Distribuição De Água Na Região Metropolitana De Aracaju/Se Em Dmc's

Wendell Valença Bittencourt de Jesus [α], Marcos Luciano Alves Barroso [σ], Leandro Barros de Santana [ρ], José Franco de Azevedo [ω] & Zacarias Caetano Vieira [¥]

Abstract- Real losses are inevitable in water distribution; however, efficient network management can lead to minimum acceptable values. The occurrence of leaks indicates a lack of maintenance of the pipelines, inadequate installations, and large variations in pressure and flow in the network. Thus, the study aims to compare data from Measurement and Control Districts, DMCs (32 and 33), which are part of the water distribution network of the Aracaju Metropolitan Region, with regional and national data, with the perspective of identifying opportunities for improvement that aim to reduce loss rates. The Water Loss Reports of the Sergipe Sanitation Company (DESO) were utilized, adopting seven parameters that were examined in the period from 2017 to 2022, where we sought to identify trends and significant correlations. In which the DMC 32 correlation matrix demonstrated high agreement, particularly showing 66.66%, which indicates a strong correlation between the parameters. In DMC 33, the correlation matrix demonstrated low agreement (42.85%). Meanwhile, the values of the loss indexes in the DMCs (31.82 and 40.82%) showed an unsatisfactory average variation in the period, and if we compare 37.78% (Brazil), 46.67% (Northeast), and 57.60% (Sergipe) in the year 2022, they are lower but not ideal. Demonstrating that the DMCs studied reflect how distribution management operates and how the parameters taken into consideration can estimate operational losses in the water distribution network and direct the actions of sanitation companies.

Palavra-chave: *água, DMC, perdas, saneamento.*

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I. Introdução

A água é um bem essencial para a vida, mas sua disponibilidade está cada vez mais ameaçada. Historicamente, a crescente demanda por água, a poluição dos recursos hídricos e as mudanças climáticas são alguns dos fatores que contribuem para essa constante vigilância sobre a imensidão das águas (FERREIRA e GARCIA, 2017). Diante desse cenário, a promoção de pesquisas cujos resultados são processos de gerenciamentos eficientes dos recursos hídricos nos sistemas de abastecimento, são vitais.

Muitas estratégias podem ser adotadas para reduzir o desperdício e promover uma adequada administração dos recursos hídricos, no entanto o estudo deve ser embasado por meio de análises e discussões do controle e segurança da água, dos parâmetros para análise de perdas e na identificação das oportunidades mais adequadas para reduzir ou até mitigar esse desperdício. A gestão deste insumo essencial para a sociedade torna-se tão importante sobre os desafios de distribuição quanto se pensa (PEREIRA e TINOCO, 2021).

Barroso (2019), em seus estudos alega que, apesar da existência de certo nível de planejamento para gestão da distribuição, muitos fatores ainda não são considerados. No parâmetro equidade de acesso, as gestões falham no quesito assertividade entre reparo e aumento de distribuição (FRITZ, GIMENES, PINA, 2020).

Uma má gestão da rede de distribuição pode levar a perdas significativas de água potável, por meio de vazamentos e tubulações danificadas (CASTRO, 2022). A ocorrência de vazamentos apresenta como causas mais frequentes a ausência de manutenção da tubulação (PEREIRA e TINOCO, 2021).

Para o planejamento do controle de perdas, companhias responsáveis pela distribuição de água utilizam os Distritos de Medição e Controle (DMC), que são subáreas, de parte da rede, delimitadas e isoladas com controle de vazão na entrada. Os DMC's são

importantes para uma distribuição mais eficiente, pois com auxílio de equipamentos e de pessoal treinado permitem a agilidade na identificação de vazamentos, analisam de forma mais criteriosa o consumo de água da área delimitada por meio da macro e micromedição, controlam a pressão de água na rede, melhoram o acompanhamento das perdas (Real e Aparente). E assim, facilitando o controle de uma determinada área e fazendo com que a companhia consiga desenvolver ações com mais foco no problema.

II. Objetivos

Coletar dados da rede de distribuição de água da Região Metropolitana de Aracaju (RMA)/SE, em dois DMC's, e comparar a dados regionais e nacionais, buscando identificar oportunidades de melhoria, fortalecimento de práticas que visem à redução dos índices de perdas na rede distribuição de água.

III. Metodologia

Com acesso aos Relatórios dos Quantitativos de Perdas Hídricas no sistema de distribuição de água, fornecido pela Diretoria de Operação e Manutenção, da Companhia de Saneamento de Sergipe (DESO) que tratam de informações da rede de distribuição de água da Região Metropolitana de Aracaju, os dados foram consolidados de dois DMC's, no período de 2017 a 2022, e foi realizada uma análise estatística.

Caracterização da cidade de Aracaju/SE - Na cidade de Aracaju, capital do Estado de Sergipe, os serviços estruturantes foram realizados apenas no começo do século XX, como água e esgoto encanados. Atualmente, já tem 602.757 habitantes, com Índice de desenvolvimento Humano de 0,770 e predominam como atividades econômicas setor de serviços e indústria, respondendo por um terço do PIB do Estado (SEPLAG, 2023).

Caracterização da rede de distribuição de água- A rede engloba, além da cidade de Aracaju, as cidades sergipanas de Nossa Senhora do Socorro, Barra dos Coqueiros e parte da cidade de São Cristóvão. A rede existente é alimentada por 4 Estações de Tratamento de Água, e é uma rede predominantemente de traçado misto, e fisicamente dividida e interligadas por 10 Setores, que são redes menores que acomodam uma gestão mais decidida.

Caracterização dos Distritos de Medição e Controle (DMC's)- São sub-áreas específicas de manobras, pequenas redes, onde são instalados Macromedidores, e Válvulas Redutoras de Pressão (VRP) para proteger as tubulações de grandes pressões, evitando seu rompimento e possibilitando assim detectar os vazamentos.

Uma das características mais marcantes da tecnologia que utiliza VRP é que sua implantação requer, uma área de atuação bem definida na rede de distribuição de água, isolada por registros limítrofes, configurando um subsetor ou um DMC (ZANIBONI, 2009). Os projetos de setorização devem buscar o equilíbrio hidráulico do sistema de distribuição de modo a se obter um sistema com pressões controladas buscando a ocorrência de perdas mínimas (MOTTA, 2010).

Para Gonçalves (1998), a primeira atividade de controle de perdas é a setorização da rede. Pode-se utilizar como forma de controle, a implantação simples do distrito de medição da vazão de entrada do setor.

A rede da Região Metropolitana de Aracaju possui cadastrados 59 DMC's, que foram definidos depois de uma avaliação técnica. E escolhidos aleatoriamente dois (DMC's), denominados DMC 32 e 33 para fazer o estudo. Sendo que o DMC 32, localizado no conjunto habitacional Santa Lúcia/Aracaju, faz parte do Setor 6 da rede, é abastecido pelo reservatório denominado R6, do tipo apoiado, possui um perímetro de rede de aproximadamente 16.105 m, tem apenas um VRP, e possui uma topografia relativamente plana.

Já o DMC 33 é localizado no bairro Siqueira Campos/Aracaju, faz parte do Setor 1, é abastecido pelo reservatório denominado R1, do tipo apoiado, com o perímetro de 10.859 m, não possui VRPs, e de topografia bastante irregular. A partir desse volume de entrada, é possível realizar um comparativo com os volumes micromedidos, de forma a proporcionar o cálculo dos volumes de água perdidos no DMC (JÚNIOR e VATAVUK, 2023).

O monitoramento dos DMC's é realizado diariamente, por meio de um programa (GRAFANA), que recebe os dados do macromedidor, nas quais os pulsos são convertidos em vazão e enviados através do Datalogger, gerando relatórios.

Tratamento estatístico e parâmetros de avaliação- Foram utilizados os dados mensais de 7 parâmetros dos dois DMC's no período de 2017 a 2022. Foram adotados seguintes parâmetros de avaliação conforme o SNIS (Brasil, 2022): Número de economias; Número de ligações; Volume distribuído; Volume micromedido; Volume faturado; Dias faturados e Índice de perdas: Porcentagem de água perdida que sai do reservatório, chega até a entrada do DMC, mas que após a macromedição, esse volume de água não retorna financeiramente a companhia. Para o cálculo do Índice de Perdas (*IP*) foi utilizada a razão entre a diferença do Volume Distribuído (*Vd*) pelo Micromedido (*Vm*) e o Volume Distribuído (*Vd*) (Equação 1):

$$IP = Vd - VmVd \quad (1)$$

Desta forma os dados coletados foram tabulados e alinhados numa planilha (Excel), dentro do

intervalo observado, foram identificadas as tendências e as correlações significantes entre os parâmetros. Os indicadores são apresentados de forma anualizada, ou seja, totalizados por ano, para diluir o efeito da sazonalidade no abastecimento e as diferenças entre os períodos de leitura dos volumes fornecidos e consumido na área (SANTOS, 2013).

IV. Resultados E Discussões

Tabela 1: Número de economias nos DMC's (32 e 33), no período de 2017 a 2022

Ano	Número de economias (Unid) DMC's	
	32	33
2017	2.744	1.533
2018	3.094	1.512
2019	3.719	1.507
2020	3.786	1.487
2021	3.839	1.503
2022	3.964	1.503
Média	**3.524**	**1.507**

Nota-se um comportamento diferente entre os DMC's no decorrer dos anos, onde no DMC 32, houve um aumento de 12,75% entre os anos de 2017 e 2018, e entre os anos de 2018 e 2019 houve um aumento mais considerável de 20,20%. Nos anos subsequentes, o aumento foi menos intenso, não ultrapassando 6,59%, representando menos de 150 economias instaladas. O resultado encontrado é condizente uma das características do local, ou seja, franco crescimento, recebendo novos domicílios. Já para o DMC 33, tendo uma pequena queda entre os anos de 2017 e 2020 (4,0%) e permanecendo inalteradas nos anos seguintes, isto é, um local consolidado, de poucas áreas para serem ocupadas, não houve grandes alterações. Vê-se também que no DMC 32 a média do número de economias ficou em torno de 3.524 unidades, enquanto no DMC 33 foi de 1.507 unid., praticamente tem-se o dobro de unidades instaladas.

Quanto ao Número de ligações- Visando melhorar a contabilização do volume consumido, recomenda-se que todas as ligações sejam hidrometradas, e o período de contabilização do volume produzido coincida com o período da leitura dos hidrômetros, permitindo assim comparações coerentes (GONÇALVES, 1998).

A Tabela 2 expõe os dados de número de ligações ativas existentes nos DMC's. Assim, pode-se perceber que no DMC 32 houve uma crescente no número de ligações ativas, ao longo dos anos, sendo mais notável entre os anos 2017/2018 (18,87%) e 2018/2019 (23,18%), que pode estar ligado ao crescente número de imóveis na região, tendo um aumento de mais de 52,63% no período, no número de ligações, mantendo-se uma média de 3.188 ligações ativas.

Tabela 2: Número de ligações ativas nos DMC's (32 e 33), no período de 2017 a 2022

Ano	Número de ligações (lig.) DMCs	
	32	33
2017	2.337	1.321
2018	2.778	1.305
2019	3.422	1.301
2020	3.482	1.287
2021	3.543	1.302
2022	3.567	1.313
Média	**3.188**	**1.305**

Diversos autores como Gomes (2011) e Lambert & Taylor (2010) relatam que em áreas urbanas a dimensão média para, DMC's deve estar compreendida entre 500 e 3.000 ligações, porém, não se recomenda valores acima das 5.000 ligações, pelo fato de se tornar mais difícil a localização de vazamentos. Segundo Motta (2010) em muitos centros urbanos, que experimentaram crescimento populacional acelerado, as redes de distribuição avançam para atender às novas ocupações sem preocupação coma setorização dos sistemas de água. Já no DMC 33 aconteceu o inverso onde entre os anos de 2017 e 2020 houve uma pequena queda no número de ligações (2,64%), que pode ter acontecido devido a supressões de água sem solicitação de religação, além de ser uma região já densamente povoada com menos áreas para crescimento, e nos anos seguintes voltou a crescer o número de ligações (2,02%), ficando com uma média de 1.305 ligações ativas no período.

Ainda quando analisamos a relação economias/ligações nos dois DMC's, tem-se 1,10 econ./lig. pouco abaixo da média nacional, 1,28 econ./lig. (BRASIL, 2022), e no mesmo ano tem-se 1,54 econ./lig. para o DMC 32 acima da média nacional.

Quanto ao Volume distribuído de água- No DMC 32 com vazão média de entrada de 95,90 m³/h (DESO, 2022), apesar de ter uma queda no volume distribuído entre 2017/2018 representando 2,25% (Tabela 3), houve no geral, uma crescente tendo uma média de aumento de 5.000 m³ por ano a partir de 2018, sendo entre 2018 e 2019 foi o mais acentuado de 7.125 m³ (15,40%) e o menor entre 2019/2020 de 1.887 m³ (3,53%)que pode ter sucedido, assim como no número de ligações, e ao pico da Pandemia (COVID 19) onde foi consumido mais água para fins higienização mais assídua, e possíveis perdas na distribuição com uma média no volume distribuído (54.577 m³) no período, representando um aumento de 17.687 m³.

Tabela 3: Variação do volume distribuído de água nos DMC's (32 e 33), no período de 2017 a 2022

Ano	Volume distribuído (m³) DMCs	
	32	33
2017	47.320	23.849
2018	46.253	30.919
2019	53.378	27.816
2020	55.265	26.229
2021	60.237	30.712
2022	65.007	29.145
Média	**54.577**	**28.112**

No DMC 33 com vazão média de entrada de 40,55 m³/h (DESO, 2022) diferentemente DMC 32, houve um aumento do volume distribuído (29,64%) entre 2017/2018, já entre 2018/2020 houve uma redução do volume (15,16%), voltando a crescer entre 2020/2021 em 17,09%, assim como no DMC 32, devido também ao pico da Pandemia (COVID 19) ou aos possíveis vazamentos, e reduzindo entre 2021/2022, final da pandemia (5,10%), tendo uma média entre os anos (2017/2022) de 28.112 m³ de água distribuída para os consumidores do bairro. Outra questão importante para ser verificada no DMC é a vazão mínima noturna. Segundo Farley *et.al* (2008), a vazão mínima noturna é a menor vazão de entrada no DMC, e quando como o consumo é mínimo e as perdas por vazamentos atingem os níveis máximos.

Quanto ao Volume micromedido- Analisando a Tabela 4 a seguir que trata do volume micromedido de água, que é aquele medido nos hidrômetros instalados em ligações prediais têm-se que, no DMC 32 houve um aumento de 13.402 m³ (46,08%) em sua micromedição ao longo do período estudado, assim como o volume distribuído, mas em maior intensidade, sendo os aumentos mais consideráveis do volume micromedido entre 2017/2018 (2.724 m³), 2018/2019 (6.367 m³) e entre 2019/2020 (3.051 m³), nos anos restantes os aumentos foram menos expressivos (< 950 m³).

Tabela 4: Variação do volume micromedido nos DMC´s (32 e 33), no período de 2017 a 2022

Ano	Volume micromedido(m³) DMC's	
	32	33
2017	29.082	16.912
2018	31.806	16.132
2019	38.173	16.949
2020	41.224	16.356
2021	41.545	15.885
2022	42.484	16.643
Média	**37.386**	**16.480**

No DMC 33 foram constatados que não houve grandes alterações do volume micromedido de água, valendo ressaltar o que aconteceu entre 2017/2018 e 2020/2021 que o volume distribuído aumentou (29,64 e 17,09%) e o volume micromedido reduziu (4,61 e 2,88%), o que causou um provável prejuízo a companhia devido à queda de faturamento, já em 2018/2019 e 2021/2022 houve uma diminuição do volume distribuído e um aumento no micromedido (5,06 – 4,77%) fazendo com que a companhia tivesse um aumento no faturamento e reduzisse a perda.

A base de cálculo do índice do consumo médio *per capita* diário do SNIS-AE é o volume de água consumido, micromedido (BRASIL, 2022a). Segundo o diagnóstico do SNIS o consumo médio *per capita* de água no Brasil, foi de 148,20 l/hab.dia (BRASIL, 2022). No entanto, no mesmo documento informa que foi de 133,57 l/hab.dia na cidade de Aracaju/SE, 16,63 litros menores.

Quanto ao Volume faturado- Verifica-se, de acordo com as medições da Tabela 5, nos dois DMC's, que o comportamento do volume faturado, mostrou-se realista, pois os valores são maiores que o do volume micromedido. Isso se deve ao fato que, as companhias adotam parâmetros de consumo mínimo ou médio, que podem ser superiores aos volumes efetivamente consumidos.

Tabela 5: Variação do volume faturado nos DMC's (32 e 33), no período de 2017 a 2022

Ano	Volume Faturado (m³) DMC's	
	32	33
2017	34.440	20.772
2018	38.443	20.176
2019	45.946	20.784
2020	48.113	19.968
2021	48.737	19.757
2022	49.797	20.543
Média	**44.246**	**20.333**

Nota-se no DMC 32, que o volume anual de água debitado ao total de economias, houve no decorrer dos anos, uma crescente (15.357 m³) no volume faturado, sendo os maiores aumentos entre os anos 2017/2018 e entre 2018/2019 de 7.506 m³ (19,52%). Nos anos subsequentes não foram constatados sobressalentes aumentos no volume faturado e a média de 44.246 m³, com um aumento significativo de 44,59% no período. Esse percentual representa a fração do volume de água disponibilizado que foi faturado por ter sido contabilizado como volume utilizado pelos consumidores.

Já no DMC 33, assim também como no volume micromedido, não foram constatadas grandes alterações, apresentando uma pequena queda (1,10%), e uma média de 20.333 m³ no período analisado. Assim, como a tendência é de sempre existir algum nível de inadimplência, é provável que os valores realmente faturados sejam maiores que os informados.

Segundo Freire (2017) é importante salientar que volume não-faturado é diferente do componente perda.

Quanto aos Dias faturados- Com relação aos dias faturados não se percebe grandes oscilações, o que se nota é que no DMC 32 na maioria dos anos a média de consumos entre os meses foi de 31 dias, e no DMC 33 a média foi de 30 dias. Estes dados de maneira geral não influenciam os demais parâmetros.

Quanto aos Índices de perdas- É importante ressaltar que, não existe perda nula. As perdas de água ocorrem em todos os sistemas de abastecimento, apenas a quantidade perdida é que varia (MELATO, 2010). Na Tabela 6 abaixo, tem-se os índices percentuais de perdas dos DMC's.

Tabela 6: Desempenho do Índice de Perdas nos DMC's (32 e 33), no período de 2017 a 2022

Ano	Índice percentual de perdas (%) DMC's	
	32	33
2017	37,98	32,70
2018	34,10	44,03
2019	28,36	38,98
2020	25,40	38,47
2021	30,99	48,21
2022	34,15	42,51
Média	**31,82**	**40,82**

Pode-se notar que no DMC 32, existe uma diminuição das perdas, relevante ao longo dos anos 2017/2020 (37,98% para 25,40%), e dentre esses os anos de 2018/2019 tiveram a maior redução, gerando assim menos desperdício de água. A partir de 2020 até 2022 o índice de perdas voltou a crescer (8,75%) encerrando com 34,15% e tendo uma média no período de 31,82%. No período analisado (2017-2022) o índice de perdas teve uma redução de 3,83 pp. Em termos quantitativos, o índice significa que, de cada 100 litros disponibilizados pela companhia apenas 68,18 litros são contabilizados como utilizados pelos consumidores.

Já no DMC 33 o comportamento foi bem diferente, onde houve uma forte alta entre os anos 2017/2018 (32,70% - 44,03%) e logo após vieram duas reduções entre 2018/2020 (5,56 pp). Após isso entre 2020/2021 aconteceu uma forte alta (9,74 pp) e em seguida uma queda de (5,70 pp), terminando 2022 com 42,51% de perdas e na média entre os anos 40,82% sendo um aumento de 9,81 pp no período (2017/2022) e uma perda de 9,0 pp maior, se comparado com o DMC 32.

Os dados se comparamos aos 37,78% (Brasil), 46,67% (Nordeste) e 57,60% (Sergipe) do BRASIL (2022), são menores, porém não ideais, isto é, indicam que os investimentos em curso não conseguiram reduzir, de maneira significativa as perdas. A atualização do cadastro comercial também é de grande importância para o combate as perdas aparentes, por isso devem ser feitas em caráter permanente (SANTOS, 2013).

Os índices de perdas na distribuição de água no Estado de Sergipe nos anos de 2021 e 2022 foram altíssimos de 57,6% e 48,4% com uma variação absoluta de 9,2 (BRASIL, 2022). O que se observa, é a paridade com a média regional, em face dos desafios socioeconômicos serem similares, analise já vista por SILVA (2014). Reduzir essas perdas é uma das atividades que vai além de oferecer retorno financeiro imediato (MORAIS, CAVALCANTE, ALMEIDA, 2010).

Para Motta (2010) o controle de pressões na rede de distribuição tem impacto imediato nos volumes de perdas. Através de análises de históricos de vazões antes e depois da implantação de uma válvula redutora de pressão é possível observar claramente o ganho em volume, uma vez que as vazões de vazamentos são reduzidas a partir da entrada em operação da válvula. A manutenção preventiva e a adoção de procedimentos operacionais e treinamento de pessoal para a realização de manobras adequadas é vital para que se evitem rompimentos causados por aumentos súbitos de pressão (DA SILVA, DELLA, BACK, 2014).

Estudo de matrizes de correlação dos dados dos DMC's- A análise de correlação foi realizada utilizando os dados médios dos 7 parâmetros medidos nos DMC's, sendo correlacionadas as variáveis físicas e o indicador para a determinação de correlações estatisticamente significantes.

Assim a matriz de correlação originaria dos dados médios do DMC 32 (Tabela 7) demonstrou, de um modo geral, elevada concordância, particularmente representando 66,66%, que indicam uma forte correlação (> 0,50) entre os parâmetros. Dessa matriz, é possível a observação de correlação significativa positiva (> 0,88) entre Volume faturado e os parâmetros Nº de Economias, N° de ligação, Volume Distribuído e Volume Micromedido.

Tabela 7: Matriz de correlação dos parâmetros com base nos dados médios, no DMC 32

DMC 32	Nº de Economias	Nº de Ligações	Volume Distribuído	Volume Micromedido	Volume Faturado	Dias Faturados	Índices de Perdas
Nº de Economias	1						
Nº de Ligações	0,9956943	1					
Volume Distribuído	0,8754953	0,8332077	1				
Volume Micromedido	0,9875349	0,9786852	0,9031343	1			
Volume Faturado	0,9968859	0,9917520	0,8870240	0,99656955	1		
Dias faturados	0,0212627	-0,0328591	0,3696542	0,15262126	0,0825138	1	
Índices de Perdas	-0,6668382	-0,7162438	-0,2687742	-0,64894643	-0,6663048	0,3503853	1

O que reflete a importância do acompanhamento do volume faturado, pois, de acordo com a análise pode-se constatar que existe uma associação muito ampla entre eles. E, portanto, quando o Volume Faturado aumenta, os outros parâmetros têm

uma forte tendência a aumentar, indicando que esses parâmetros estão relacionados e que podem variar juntos.

Uma forte correlação entre Volume Distribuído e Volume Micromedido (> 0,90) indica que, na maioria dos casos, quando o Volume Distribuído aumenta o Volume Micromedido também aumenta de forma substancial. Isso significa que um parâmetro pode ser utilizado para prever o outro, mas que não necessariamente uma variável irá acarretar a outra, observando-se também o aumento do Volume Faturado devido à forte correlação positiva com os dois parâmetros (> 0,88 e > 0,99). Já as correlações significativas negativas (< - 0,64) dos Índices de Perdas com os 4 parâmetros, N° de Economias, N° de ligação, Volume Micromedido e Volume faturado indicam que os parâmetros se deslocam em sentidos opostos destacando que, quando o Índice de Perdas aumenta, os outros 4 parâmetros tendem a reduzir fazendo com que menos imóveis sejam atendidos, menos água seja distribuída, micromedida e faturada sendo um grande desafio para a melhora do sistema de distribuição de água.

Já a matriz de correlação originaria dos dados médios do DMC 33 (Tabela 8) demonstrou, de um modo geral, baixa concordância, particularmente 42,85%.

Tabela 8: Matriz de correlação dos parâmetros com base nos dados médios, no DMC 33

DMC 33	N° de Economias	N° de Ligações	Volume Distribuido	Volume Micromedido	Volume Faturado	Dias faturados	Índices de Perdas
N° de Economias	1						
N° de Ligações	**0,8635312**	1					
Volume Distribuido	-0,3700231	-0,2138052	1				
Volume Micromedido	0,4291956	0,4277748	**-0,6966519**	1			
Volume Faturado	**0,5993748**	**0,6185473**	**-0,5148708**	**0,9475834**	1		
Dias faturados	-0,4145780	-0,0233152	0,2674593	-0,0817899	-0,0587257	1	
Índices de Perdas	-0,4703762	-0,2977106	**0,9510190**	**-0,8115598**	**-0,690001**	0,195023	1

Embora essa correlação negativa só tenha ocorrido fortemente (< -0,81) entre o Índices de Perdas com Volume Micromedido demonstrando que quanto maior a água micromedida menor a será a perda, quando comparado com os outros parâmetros o Índice de Perdas teve correlação negativa (com maior ou menor intensidade) com praticamente todos, exceto Volume Distribuído, mostrando que eles estão opostamente relacionados e que o Índice de Perdas só diminuiu quando os outros parâmetros se elevaram.

Ao mesmo tempo uma forte correlação positiva (> 0,95) entre o Índice de Perdas e o Volume Distribuído constatando-se que quanto mais água foi distribuída pela companhia, mais água foi perdida. Torna-se possível concluir, pela associação do desperdício de água com a dinâmica de combate as perdas, que apesar de um maior Volume Distribuído não houve contribuição para o aumento do Volume Faturado, pois o mesmo só obteve acréscimo quando comparado com o Volume Micromedido onde obtiveram alta correlação (> 0,94).

V. Conclusão

Após avaliação dos dados dos Relatórios dos Quantitativos de Perdas Hídricas (DESO, 2022) em dois DMC's da rede de distribuição de água da Região Metropolitana de Aracaju, conclui-se que: A instalação dos DMC's não traz nenhum tipo de prejuízo a rede de distribuição de água da Região Metropolitana de Aracaju; Os DMC's estudados são um reflexo de como as gestões de distribuição atuam, e quais os parâmetros são levados em consideração para estimar as perdas operacionais; Tornou-se importante atualizar os dados consolidados sobre percentuais de perdas, e estratifica seus desdobramentos, seja em arrecadação, em volume de água distribuída, frente ao aumento de economias e as dinâmicas sociais; As perdas de água nesses locais representam uma parcela significativa do total de perdas, o que impacta negativamente a eficiência operacional e financeira da companhia; As perdas de água nos distritos de medição e controle são atribuídas aos vazamentos em equipamentos de medição, falhas em válvulas e registros, além de problemas de calibração e manutenção inadequada; A falta de tecnologias avançadas de monitoramento e detecção de vazamentos dificulta a identificação e correção desses problemas de forma rápida e eficiente.

Por tudo, abaixa redução das perdas de água nos distritos de medição requer mais esforços conjuntos das autoridades públicas, companhias de água e comunidades locais.

E para novos estudos e projetos da companhia recomenda-se que: Seja implantado para os DMC's o Sistema de Informação Geográfica (SIG), pois será uma ferramenta de suporte à gestão de perdas; Sejam implantados os sistemas de telemetria, pois permitem a agilidade na obtenção de informações e a tomada de decisões na operação da distribuição de água; Nos relatórios da companhia incluam o parâmetro, vazão de entrada no DMC, a medição de vazão em redes, é um fator importante no controle de perdas, pois sua correta utilização tem influência direta nos índices de perdas (TSUTIYA, 2004); Nos relatórios da companhia incluam o parâmetro, pressão mediana DMC. Pois, o gerenciamento de pressões pode ser definido como uma prática de gestão das pressões do sistema de abastecimento (THORNTON & LAMBERT, 2005).

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Enhancing Sustainable Poultry Farming through Modern Agricultural Technologies: Bridging the Adoption Gap in Southwest Nigeria

By Dr. Victoria Madedor

Abstract- The poultry industry in Nigeria, the largest in Africa, plays a vital role in national food security, rural livelihoods, and the supply of raw materials to industries such as pharmaceuticals, hospitality, and agriculture. Despite its potential, the sector remains constrained by persistent challenges including high mortality rates, frequent disease outbreaks, and limited technological integration, particularly with respect to real-time monitoring and automated systems. While modern agricultural technologies such as the Internet of Things (IoT) offer promising solutions for enhancing productivity and sustainability, their adoption in Nigeria remains limited. However, the empirical gap in understanding the specific barriers to technology adoption among small and medium-scale poultry farmers in Southwest Nigeria has received little attention. This study addresses this gap by investigating the awareness, perceptions, and adoption challenges of IoT-based agricultural technologies among poultry farmers in Oyo, Ogun, and Lagos States. Anchored in Production Theory and employing a descriptive survey design, primary data were collected from 240 poultry farmers using structured questionnaires.

Palavra-chave: *sustainable poultry farming, internet of things (IoT), agricultural technologies, technology adoption, nigeria.*

GJSFR-H Classification: *LCC: S671.5, S494.5.I57*

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Keywords: sustainable poultry farming, internet of things (IoT), agricultural technologies, technology adoption, nigeria.

I. Introduction

The poultry industry is a pillar of Nigeria's agricultural economy, playing a crucial role in food security, employment generation, and the supply of essential raw materials to ancillary industries including hospitality, pharmaceuticals, and textiles(Ajala et al., 2021). With approximately 180 million birds and an estimated net worth exceeding 300 billion Naira, the sector contributes about 25% to the agricultural GDP and supports the livelihood of 14 million Nigerians(Olutumise et al., 2023). This growth is fueled by broiler production, particularly concentrated in Southwest Nigeria, where cultural and religious acceptance, coupled with intensive production systems, have made poultry an attractive venture for smallholders and commercial investors alike(Chiekezie et al., 2022).

Globally, the demand for animal protein has risen, with projections indicating a 60% increase in poultry product demand in Africa by 2030, positioning Nigeria as the continent's largest market(Nkukwana, 2019). Yet, despite its economic significance and growth potential, the sector is constrained by persistent challenges such as high mortality rates, disease outbreaks, substandard chick quality, limited veterinary access, high feed costs, and inadequate extension services(Wongtangtintharn et al., 2025). Notably, the COVID-19 pandemic exposed the fragility of existing food systems, highlighting the need for resilient and sustainable models.

To address these inefficiencies and promote sustainable intensification, there is a need to harness the potential of disruptive agricultural technologies (DATs), particularly the Internet of Things (IoT)(Harsanto et al., 2025), which can empower farmers by accelerating agri-food outcomes by multiple folds. IoT enables real-time monitoring of environmental conditions, disease symptoms, and animal behavior via sensor-based data collection and automated responses. Applications range from regulating temperature and humidity in poultry houses to early detection of diseases such as Avian Influenza and Newcastle Disease, both of which have been endemic and devastating in Nigeria(Ojo et al., 2022).

However, while the theoretical and practical benefits of IoT in poultry farming are well-documented, adoption remains limited. The authors acknowledge the promise of smart farming, and base this research on the inadequacy of empirical studies investigating actual adoption dynamics among Nigerian poultry farmers, particularly in Southwest states like Oyo, Ogun, and Lagos. Some of the existing studies focus have focused on general agricultural technology usage, leaving a critical gap in understanding the perceptions, awareness levels, and barriers to IoT adoption in the

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poultry subsector. Afolabi et al. (2021), for instance designed a cloud-based IoT system to monitor temperature and humidity on Nigerian poultry farms and they reported how low-cost sensor technology can help farmers to monitor their farms remotely. Likewise, Kumar et al. (2020) also conducted a systematic review of IoT use in the area of poultry health and welfare management, and they emphasized that these technologies can help to better manage animal welfare and should be integrated into poultry farming practices in Nigeria.

This study aims to bridge the gap between technology use and perception barriers by exploring the socio-economic characteristics, awareness, perceptions, willingness to adopt, and constraints faced by poultry farmers in integrating IoT technologies into their operations. The authors base this study on the Production Theory and the Rational Choice Theory, both of which posit that adoption decisions are influenced by expected gains in productivity, findings provides practical insights that can inform targeted interventions. the result will benefit both farmers and researchers interested in adopting DAT (IoTs). Findings will benefit both stakeholders and extension agents on which disruptive technology is most efficient and which is not, and will help smallholder farmers adopt improved poultry production technologies as they aim to expand their current stock and increase productivity.

II. Methodology

The study was carried out in the south-western part of Nigeria, with a focus on Lagos, Ogun and Oyo states. Apart from agriculture, which is the major economic activity in many of the rural communities of this area, the zone is also known for its commerce and trading activities with a preponderance of micro, small, and medium indigenous industries that are into manufacturing, fabrication, and agro-allied produce. This zone was selected because commercial poultry production is more developed in the south-western part of the nation.

Study population included poultry farmers in Oyo, Ogun and Lagos states and the multi-stage sampling techniques were used to randomly select 40 broiler farmers from 2 Local Government Areas (LGAs) within each state, which was purposively selected using data obtained from the Poultry Association of Nigeria (PAN). Data was collected with the use of a structured questionnaire which was carefully designed to reflect the study's objectives and to capture both qualitative and quantitative responses from poultry farmers.

The focus of the study was on understanding poultry farmers' awareness of and willingness to adopt Disruptive Agricultural Technologies. This was measured using a Likert scale (1-5), which allowed respondents to express varying degrees of agreement or disagreement. Alongside this, the study also examined several socio-economic factors like age, sex, marital status, education, farming experience and household size that could influence their responses.

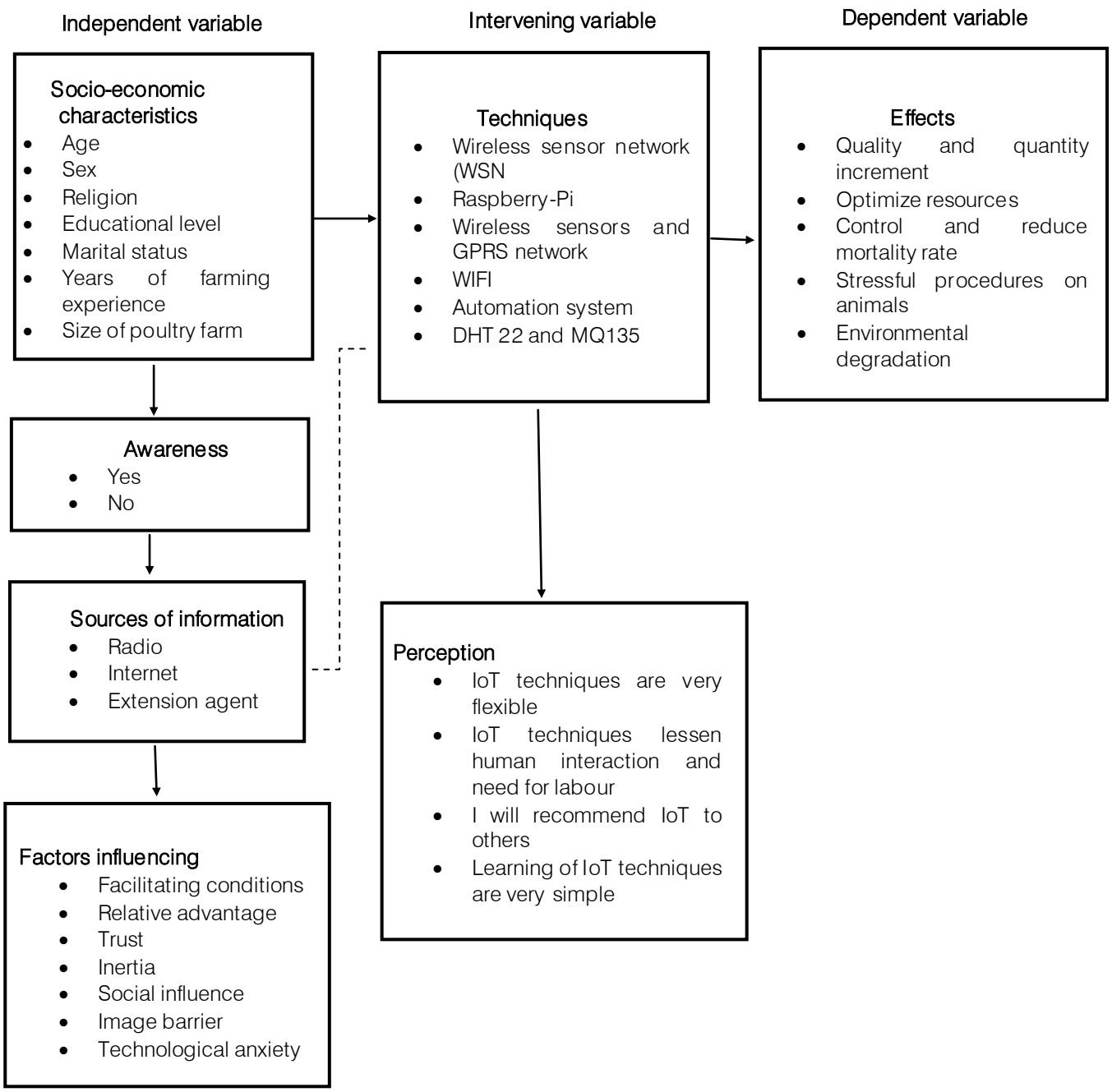

Figure 1: Conceptual Framework

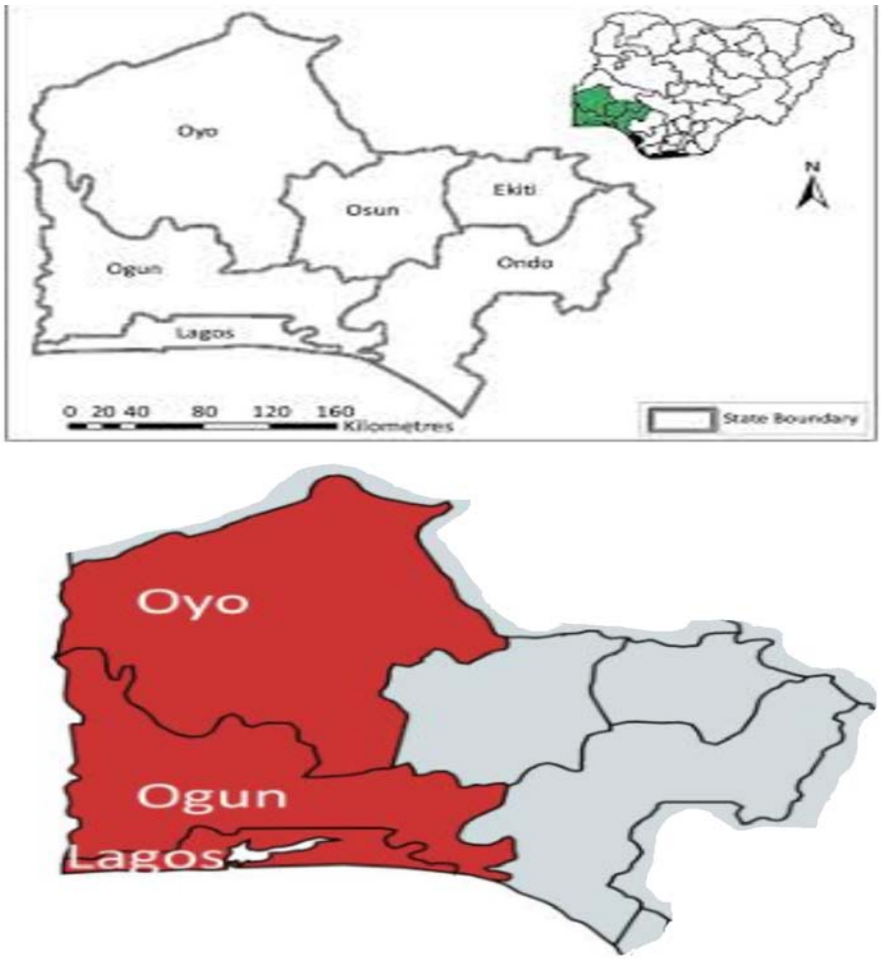

Figure 2

III. Results

A total of 240 questionnaires were distributed across poultry farmers in Southwest Nigeria, with 201 completed and returned, yielding a response rate of 83.75%. Analysis of socio-economic characteristics revealed that most respondents (48.26%) were aged 26–40, followed by 41–60 years (31.84%), with a mean age of 47, indicating a largely active and productive population. The majority were male (70.15%) and married (65.17%), and a significant number (66.67%) had completed tertiary education. In terms of farming experience, 43.28% had 11–20 years of experience, and the average was 19 years.

Regarding size of the enterprise, 38.81% of farmers had fewer than 2,500 birds, 29.35% had 2,501–5,000 birds, and 31.84% had more than 5,000 birds, classifying most as medium-scale farmers. Over half (57.71%) raised both layers and broilers, and 74.13% operated a mix of intensive and extensive systems. For land ownership, 56.22% purchased their land, while others leased (19.40%) or used family land (24.38%). Urban farm locations were more common (61.19%), and 52.24% of respondents were members of the Poultry Association of Nigeria (PAN).

IoT (Internet of Things) technology adoption was fair, with 52.74% of the respondents stating that they were already using IoT solutions, while 47.26% were not. PAN was the main source of IoT information (38.80%), followed by extension agents (33.83%). Most users (62.26%) had less than a year's experience with IoT technologies, while 83.96% expressed willingness to adopt them. In terms of specific technologies, farmers were most aware of biogas (83.58%), automated systems like heaters and feeders (82.09%), and GPRS/mobile systems (74.63%). Awareness was lowest for satellite-enabled remote monitoring (50.75%).

When ranking levels of awareness, respondents were most aware of GPRS and mobile systems, followed by wireless sensors and biogas, with an overall IoT awareness index of 2.09. Perception-wise, most respondents believed IoT could monitor climate (55.72%), detect disease (53.73%), and increase profitability (58.21%). However, constraints such as lack of resources, knowledge, and compatibility were noted. The overall perception index stood at 2.33.

Willingness to adopt specific IoT tools was highest for IoT and WiFi (45.27% very willing), biogas (40.80%), and satellite monitoring (43.29%), with an overall willingness index of 1.83. A logistic regression

analysis found that educational level ($p < 0.05$), stock size ($p < 0.05$), farming experience ($p < 0.1$), and years of IoT use ($p < 0.05$) significantly influenced willingness to adopt disruptive agricultural technologies. For example, a 10% increase in farming experience increased willingness by 17%, and a similar increase in stock size boosted it by 17.7%.

Constraints to poultry farming were categorized into financial, social, institutional, and management. The top constraints included lack of credit facilities (56.72% rated it very severe), poor government support (27.36% very severe), and high feed costs (50.25% very severe). Other notable challenges were pest and disease outbreaks, poor housing, erratic power supply, waste management, and poor veterinary services.

Key barriers to adoption were financial and infrastructural. Specifically, 54.73% of respondents cited cost of equipment, internet unreliability, and lack of technical knowledge as major obstacles. Additional factors included low trust in technology providers, technological anxiety, and fears of data misuse. Complexity in system setup, high maintenance costs, and limited compatibility with existing infrastructure further dissuaded adoption. Socio-cultural factors such as peer influence, media exposure, and normative pressures also played a role in shaping farmers' perceptions.

Despite these challenges, the majority of respondents expressed willingness to adopt IoT technologies if given adequate support. This willingness was positively influenced by perceived usefulness, ease of use, and potential profitability. Innovativeness and social influence emerged as important determinants of behavioral intention, especially among younger farmers.

Table 1: Socio-economic characteristics of respondents (Demography)

Age (years)	Freq.	Percent
<25	16	71.96
26-40	97	48.26
41-60	64	31.84
>60	24	11.94
Mean	47	
Sex	**Freq.**	**Percent**
Male	141	70.15
Female	60	29.85
Marital Status	**Freq.**	**Percent**
Single	67	33.33
Married	131	65.17
Divorced	1	0.50
Widowed	2	1.00
Education	**Freq.**	**Percent**
Secondary completed	36	17.91
Tertiary attempted	31	15.42
Tertiary Completed	134	66.67
Farming Experience (years)	**Freq.**	**Percent**
1-10	54	26.87
11-20	87	43.28
> 20	60	29.85
Total	**201**	**100.00**

Source: Field Survey, 2022.

Table 2: Socio-economic characteristics of respondents (Farming System)

Stock Size (birds)	Freq.	Percent
<2500	78	38.81
2501-5000	59	29.35
>5000	64	31.84
Bird type	**Freq.**	**Percent**
Layers	22	10.95
Broilers	63	31.34
Both	116	57.71
Production System	**Freq.**	**Percent**
Intensive	45	22.39
Extensive	7	3.48
Both	149	74.13
Mode of land acquisition	**Freq.**	**Percent**
Outright Purchase	113	56.22
Lease	39	19.40
Family	49	24.38
Location of Poultry Farms	**Freq.**	**Percent**
Rural	78	38.81
Urban	123	61.19
PAN Membership	**Freq.**	**Percent**
Yes	105	52.24
No	96	47.76
Total	**201**	**100**

Source: Field Survey Data, 2022.

Table 3: Distribution of respondents by Practice and Information source of IoT

IOT Practice	Freq.	Percent
Yes	106	52.74
No	95	47.26
Source of IOT Info	**Freq.**	**Percent**
Farmers Association	21	10.45
Friends and Family	10	4.98
Extension Agents	68	33.83
Media	24	11.94
Poultry Association of Nigeria	78	38.80
Total	**201**	**100**

Source: Field Survey Data, 2022.

Table 4: Distribution of respondents by Years of IoT experience and their willingness to adopt IoT

IOT Experience (Years)	Freq.	Percent
1	66	62.26
>1	40	37.74
Willing to Adopt IOT	**Freq.**	**Percent**
Yes	89	83.96
No	17	16.04
Total	**106**	**100**

Source: Field Survey Data, 2022.

Table 5: Distribution of Awareness of Internet of Things Technologies

	IOT technologies	Aware		Not Aware	
		Freq	%	Freq	%
1	BIOGAS	168	83.58	33	16.42
2	Wireless Sensors Network	104	51.74	97	48.26
3	GPRS and Mobile System	150	74.63	51	25.37
4	Automated heaters, fans, drinkers, and feeders	165	82.09	36	17.91
5	Temperature and Relative Humidity Sensor and Air Quality Sensor	151	75.12	50	24.88
6	IoT and WiFi	144	71.64	57	28.36
7	IOT and Remote Monitoring (satellite-enabled)	102	50.75	99	49.25

Source: Field Survey, 2022

Table 6: Distribution of Level of Awareness of IoT Technologies

Level of Awareness of IoT	Very Aware		Aware		Slightly Aware		Mean	S.D.	Rank
	Freq	%	Freq	%	Freq	%			
BIOGAS	59	29.35	51	25.37	91	45.27	2.16	0.85	3rd
Wireless Sensors Network	33	16.42	97	48.26	71	35.32	2.19	0.70	2nd
GPRS and Mobile System	87	43.28	71	35.32	43	21.39	2.22	0.78	1st
Automated heaters, fans, drinkers, and feeders	79	39.30	89	44.28	33	16.42	2.05	0.92	4th
Temperature and Relative Humidity Sensor and Air Quality Sensor	80	39.80	48	23.88	73	36.32	1.97	0.87	6th
IoT and WiFi	67	33.33	63	31.34	71	35.32	2.02	0.83	5th
IOT and Remote Monitoring (satellite-enabled)	48	23.88	95	47.26	58	28.86	2.05	0.73	4th
IOT Awareness Index							2.09		

IV. Discussion

This study found that factors like educational level, stock size and farming experience inform farmers' willingness to adopt IoT technologies in southwest Nigeria, which is similar to the findings of Abioye et al. (2024). This corroborates the theory of rational choice, which suggests that rational producers adopt innovations that improve efficiency and profitability. The demographic profile (largely educated and experienced) also reflects that the study population consisted majorly of farmers with the ability and willingness to engage with digital technologies for more efficient farming.

The moderate adoption rate of IoT technologies and the high willingness to adopt in this study echo the discoveries of Gbadamosi (2023), who demonstrated the technical viability and benefits of IoT monitoring systems based on birds in Nigeria, especially in monitoring environmental parameters such as temperature. However, he described challenges to adoption that were similar to those reported in this study, like financial restrictions, bad infrastructure and limited technical knowledge as great barriers to adoption. These barriers are consistent with findings in broader literature, where costs, lack of internet reliability and digital literacy remain critical.

Shahab et al. (2024), reported that IOT and disruptive technologies can increase disease tracking and prevention through real-time data collection and analysis. However, many farmers' reluctance to adopt these techniques highlight the digital divide that exists in rural, peri-urban and urban environments. Stakeholders like the government, opinion leaders, policy makers and educators must work together to bridge this gap.

The prevalence of endemic poultry diseases such as Newcastle Disease and Avian Influenza further accentuates the importance of timely monitoring systems, yet the inability of farmers to access or operate IoT tools leaves this need unmet(Grace et al., 2024). Although the technical feasibility of IoT applications in poultry production is no longer in question, their viability within different settings, shaped by local infrastructure, economic realities, and user readiness, remains a major concern. Farmers' reliance on informal information networks also implies that peer demonstration and word-of-mouth are instrumental in the diffusion of innovation. In this regard, trust and social proof are as important as cost-effectiveness or system accuracy. Furthermore, the role of government and institutional actors is notably absent in facilitating access to smart technologies. Policy support, such as subsidies, tax waivers for agritech imports, or investment in rural

broadband infrastructure, has the potential to catalyze wider adoption. Countries such as Kenya and South Africa have shown that targeted subsidies, tax incentives, and rural broadband investments can accelerate the adoption of agricultural technologies. For example, Kenya's digital agriculture initiatives, supported by government and private partnerships, have improved small farmers' access to consulting services and mobile -based IoT tools, resulting in higher productivity and market access (Krishna, 2024) Likewise, the integration of IoT training into agricultural extension programs could address existing knowledge gaps.

Socio cultural factors, such as technological anxiety, low confidence in providers and improper use of data, identified in this study point out that adoption is not only a matter of economy or infrastructure, but also of trust, perceived risk and social norms. Younger farmers and those with greater innovation have shown greater behavioral intention to adopt IoT, consistent with global studies on technology acceptance models.

While the willingness to adopt IoT among farmers indicates a readiness for change, their current environment, both physical and institutional, is not sufficiently enabling. The gap between perceived usefulness and actual usage suggests that adoption decisions are shaped as much by systemic enablers as by individual attitudes or capabilities. Thus, for Nigeria's poultry sector to fully benefit from digital transformation, a multi-stakeholder approach that combines infrastructure development, policy incentives, and targeted farmer education must be prioritized.

V. Conclusion and Recommendations

While poultry farmers in Southwest Nigeria are moderately aware of IoT technologies and perceive them as potentially beneficial, their adoption is hindered by financial limitations, poor infrastructure, and insufficient technical support. Nonetheless, the willingness to adopt remains promising, particularly if enabling conditions are improved. To accelerate adoption, it is essential to provide subsidised access to IoT tools, invest in rural digital infrastructure, and incorporate targeted training through extension services. Demonstration farms, public-private partnerships, and clear regulatory frameworks will further support the integration of IoT into poultry farming, ultimately promoting productivity, sustainability, and resilience in the sector.

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Longitudinal and Transverse Dispersion - Diffusion in Streams: Its Effects in "Complete Mixing" Condition, and the Role a New State Function

By Alfredo José Constaín Aragón

University of Cauca

Abstract- In environmental impact studies on natural flows, the concept of "complete mixing" linked to the flow's "assimilation capacity" is usually presented in terms of transverse diffusion alone, ignoring the fact that it is a joint mechanism with longitudinal dispersion. This article presents a new approach in which a state function comprehensively describes how the two mechanisms act in unison, facilitating the interpretation and calculation of the "mixing length." The developed equations are applied to the study of three different channels, obtaining satisfactory results, converging with those calculated from Elder's transverse diffusion coefficient.

Keywords: *assimilation capability of streams, state functions, tracers.*

GJSFR-H Classification: *LCC: GB659.8*

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I. Introduction

a) Paper Size, Margins, Columns and Paragraphs

For environmental impact studies, it is vital to know the dynamics of conservative solutes moving in a flow, which simulate quite well the behavior of the pollutants poured in, and are therefore important for their understanding, control and mitigation. [1] In this perspective, the calculation of the transport coefficients, especially the one that defines the transverse diffusion, is fundamental.

J. W. Elder in his original work [2], based on theoretical considerations, found a definition of the transverse diffusion coefficient, εy, which have the following definition, with H as depth, g, as acceleration of gravity and S, as slope of the energy line:

$$\varepsilon y \approx 0.23 * H * \sqrt{H * g * S} \qquad (1)$$

But later, H.B. Fischer [3], who varied this coefficient by about 50%, found better accommodation with the experimental results. This formula is used in this Article as a reference for comparing results due to its simplicity and relative accuracy.

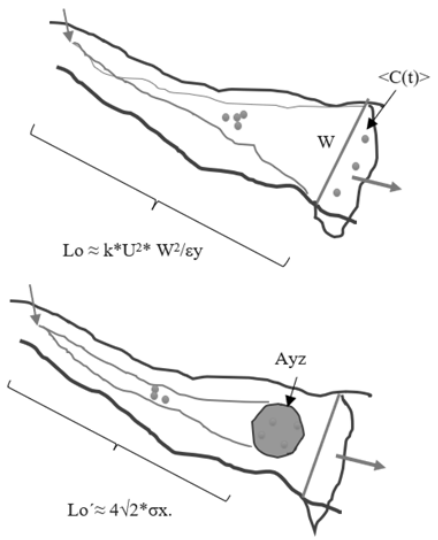
This transverse diffusion coefficient plays a very important role in understanding and defining the so-called "Mixing length", Lo, the distance at which the solute transported in a flow is considered to be "mean value" distributed in the cross section, and its concentration is a relative minimum, indicating well what the "assimilation capacity of the channel" is reached. With "k" a coefficient that depends on the way the solute is injected into the flow (k=1 for central injection), U the average velocity, and W the average width [4,5].

$$Lo \approx \frac{k*U*W^2}{\varepsilon y} \qquad (2)$$

This equation refers to the channel's "width" and is defined when the solute diffuses at an "average" value. Although the physical basis of this equation is sufficiently proven, the fact that it is affected by the "k" factor, which varies between 0.1 and 0.4 and depends on how well the injection point is located, adds an unavoidable component of imprecision.

For this reason, it is interesting to explore an alternative procedure, based on other principles, that provides greater certainty in this critical measurement.

This new procedure may be based on when the solute evenly covers the cross-section of its stream tube with a homogeneous distribution, which may or may not coincide with the channel's width. Figure 1 compares the two procedures: the classic one, corresponding to equation (2), and the new approach.



Source: Author

Figure 1: Two conditions of "complete mixing" in the evolution of a solute

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This new situation occurs when the solute transport distance is long enough for almost all of its mass (99.7%) has lost most of its interactions, and its particles are distributed homogeneously like an ideal gas (losing significantly its interactions), [6] such that, according to Gauss's Theory, there is a corresponding distance of "Six sigma", when $t \approx 4\sqrt{2}*\sigma t$, which if $U \approx \sigma_x/\sigma_t$, it holds. [7]:

$$Lo' \approx 4\sqrt{2} * \sigma_x \quad (3)$$

Defining transverse diffusion has not been easy, as there is no identifiable velocity distribution along this axis that would allow theoretical manipulation to establish mixing along this axis, as is the case on the vertical axis. [8]

In water quality studies, this "complete mixing" condition is of primary importance, given that monitoring of the variables of interest, they must have optimal representativeness, ensuring that the models run appropriately.[9] This information is typically collected in the field with tracer tests.

On the other hand, it is necessary to distinguish diffusion from dispersion [10]. The former is associated with transport caused by turbulence as a mixing agent, and on a much smaller scale by molecular motion. The second is more directly associated with the mixing and expansion effect of a solute due to the shear effect oflongitudinal velocities, arising from the mean advective velocity. The characteristic is that both types of motion are defined as proportional to the concentration gradient.[11]

Thus, while dispersion expands without limit along the longitudinal axis, transverse diffusion has a rather small limit (restricted by a finite width). Figure 2.

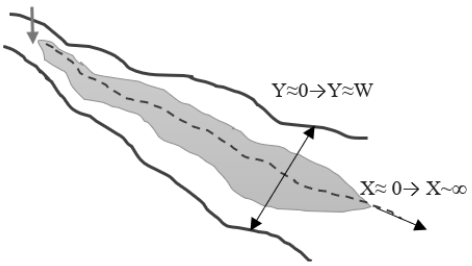

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Figure 2: Different Spatial Nature of Longitudinal and Transverse Dispersion-Diffusion

This implies that, due to this restriction, diffusion generally progresses much less rapidly than dispersion and can reach a certain equilibrium before its longitudinal portion, covering the cross-sectional area of the flow.

Then, the application of two "complete mixing" criteria must be distinguished: One: When Lo is applicable, the channel width and the transverse diffusion coefficient must be considered primarily. and Two: When Lo´ is applicable, the spatial variance of the solute curve must be considered primarily. Both criteria show important aspects of the tracer advance mechanism. The first criterion is appropriate for channels of not very great width, in which the value of "Lo" is practical for measurement. The second criterion is applied in very large rivers in which the solute behavior is well described by "Lo´", without needing to refer it to the channel width.

II. State Function to Describe the Evolution of Solutes in Turbulent Flows

a) Definition of the Function and its Relationship with the Average Flow Velocity

A transport model has been presented based not on the concept of "Dead zones" as the cause of the "non-Fickian bias" of the experimental tracer curves, but rather on the concept of heat exchange in the phenomena of "hydration" and "dilution", supported by the enthalpy of formation of the solute. [12] This evolution is described by a State Function $\Phi(t)$, fulfilling the Pfaff conditions [13] that has been applied to explain numerous experimental cases [14,15].

$$\oint d\Phi = 0 \quad (4)$$

This state function defines a one-dimensional mean flow velocity equation, similar in its quadratic structure to the Chezy-Manning mechanical equation [16]. Here $\beta \approx 0.214$.

$$U \approx \frac{1}{\Phi}\sqrt{\frac{2E}{\beta * t}} \quad (5)$$

b) Definition of the State Function in Terms of Distance

The function Φ itself is defined by clearing it from the previous equation, and putting it into function of the distance, X.

$$\Phi \approx \left(\frac{\sqrt{2E}}{U\sqrt{\beta}}\right) * \frac{1}{\sqrt{X}} \quad (6)$$

Now for two points, with X1, and $\Phi 1$, and X2 and $\Phi 2$, the following valid ratio is obtained if E does not vary significantly between each point, from eq. (5), it holds:

$$\frac{\Phi 1}{\Phi 2} \approx \frac{\sqrt{X2}}{\sqrt{X1}} \rightarrow \qquad Lo' \approx \left(\frac{\Phi 2}{0.38}\right)^2 * X2 \quad (7)$$

This equation will be useful to find distances of interest (X2) to $\Phi 2$, when $\Phi 1$ and X1 are known (this convention would be the other way around), The important thing is that the definitions are consistent with each other.

When $\Phi 1 \approx 0.38$, then the time takes the value $Lo' \approx 4\sqrt{2}*\sigma x$, that is, the "Freedom of interactions" condition for its particles.

c) Some Thermodynamic Considerations on Interactions in Very Dilute Solutions

When the solute is suddenly injected into the flow, its mass is transformed from a "solid" compound to a "liquid" compound in a first phase, [17] by means of a heat exchange. In this phase the hydration of the solute particles occurs, by the interaction with the water dipoles. Then there is the formation of structures that respond to the Coulomb interactions between the solute particles, also with a heat exchange, until they disappear when the square root of the concentration will tend to zero, according to the Hückel-Debye law for dilute concentrations. [18] In this last phase, it can be considered that the solute particles behave almost like an ideal gas, which loses its interactions and is distributed homogeneously in the volume considered.

The tendency of these mutual interactions between solute molecules to decrease can be measured in various ways, for example with the thermodynamic equations of internal pressure, "pi" [19]:

$$\left(\frac{\partial E}{\partial v}\right)_T \approx pi \tag{8}$$

This isothermal change in the "internal energy" of the gas, E, corresponds to the interactions (mutual attraction) of the gas particles, which is very small for real gases and zero for ideal gases, if internal pressure is small (low concentrations).

But perhaps the most direct way to estimate this effect is by estimating the "braking" effect that the electrostatic interactions have on the motion of the solute plume flow. In this phase, this degraded compound behaves like "Boltzmann molecular chaos," that is, erratically in all directions and therefore without any particular structure.

d) Application of the State Function, Φ(t) to the Calculation of Ratio of Discharge, According to Two Definitions of the Parameter

If the longitudinal dispersion coefficient, E, is cleared in eq. (5) it holds:

$$E \approx \frac{\Phi^2 * U^2 * 0.214 * tp}{2} \tag{9}$$

And if it is applied to the definition of Concentration (C(t) according to Fick, [20] we have:

$$C(x,t) \approx \frac{M}{Q*\Phi*tp*1.16} * e^{\frac{(tp-t)^2}{2*0.214*(\Phi*t)^2}} \tag{10}$$

The peak concentration, Cp, is then:

$$Cp \approx \frac{M}{Q*\Phi*tp*1.16} \tag{11}$$

Therefore, the discharge, Q, is:

$$Q' \approx \frac{M}{Cp*\Phi*tp*1.16} \tag{12}$$

And according to the principle of conservation of mass we have:

$$Q \approx \frac{M}{\int_a^b C(t)dt} \tag{13}$$

If the ratio, r, between these two definitions of mass is defined as:

$$r \approx \frac{Q}{Q'} \approx \frac{\left(\frac{M}{\int_a^b C(t)dt}\right)}{\left(\frac{M}{Cp*\Phi*tp*1.16}\right)} \tag{14}$$

The average value of the solute concentration is:

$$< C(t) > \approx 0.441 * Cp \tag{15}$$

Now, if $\Phi \approx 0.38$, when $tp \approx 4\sqrt{2}*\sigma t$, and the solute particles significantly lose their interactions, and considering the mean value theorem, [21], we have:

$$r \approx \frac{\left(\frac{M}{\int_a^b C(t)dt}\right)}{\left(\frac{M}{Cp*\Phi*tp*1.16}\right)} \approx \frac{Cp*0.38*1.16}{\frac{1}{tp}\int_0^{tp} C(t)dt} \approx \frac{<C(t)>}{<C(t)>} \approx 1.0 \tag{16}$$

That is, when the "complete mixing" condition is met, the two versions of the flow are equal, that is, when the interactions of the solute particles virtually disappear.

If the solute is considered as an ideal gas, its internal pressure, "pi" must comply with Clapeyron's law, with B as a physical constant. [22]

$$\frac{pi*V}{T} \approx B \tag{17}$$

For the approximate isothermal process, it is found that as the volume of the solute plume increases (which effectively occurs due to the increase in entropy), the internal pressure (and interactions) must decrease. In this way, equation (16) is fully justified since when $\Phi \approx 0.38$ is reached, the solute plume defines a volume such that its passage in time coincides with the definition of discharge in that point.

III. Classical Formulas for Calculating the Transverse Diffusion Coefficient, εY, and its Relationship with the Longitudinal Dispersion Coefficient, E.

The most notable antecedents of these calculations are the formulas proposed by Elder in the middle of the last century, where the two definitions depend on the "shear velocity", $u_* \approx \sqrt{(H*g*S)}$.[23]
The longitudinal coefficient proposed was:

$$E \approx 5.93 * H * u_* \quad (18)$$

And the transversal coefficient, as in eq. (1), corrected by Fischer, was:

$$\boldsymbol{\varepsilon y \approx 0.6 * H * u_*} \quad (19)$$

That is, both transport coefficients depend on the same dynamic factor, u_*.[24] Therefore, in general, the ratio of both coefficients "E/εy" can be established as a function "G" that depends on factors other than u_*, generally of an empirical, geometric or geomorphological nature, with different values depending on each author, and what factors they consider.[25]

$$\frac{E}{\varepsilon y} \approx \boldsymbol{G(several\ factors)} \quad (20)$$

The use of u_* as the universal dynamic root to define transport coefficients is not accidental, since frictional friction is key to understanding and defining momentum transfers between turbulent fluid layers. [26]

On the other hand, it should be considered that turbulence occurs equally along the longitudinal and transverse axes, with shear advection being the predominant differentiating factor in longitudinal dispersion.

IV. Ratio between Longitudinal and Transversal Transportation as a Function of the Respective Variances

a) "Complete Mixing" Condition for Longitudinal Transport as Function of Longitudinal Variance

Longitudinal dispersion develops in an unconstrained scenario, as in Figure 3, showing how at $t \approx 4\sqrt{2}*\sigma t$, and at $Lo' \approx 4\sqrt{2}*\sigma x$, the solute reaches the condition of loss of interactions. This "complete mixing" condition for the curve is defined from the origin to the point where there *is only one time (space) variance*.

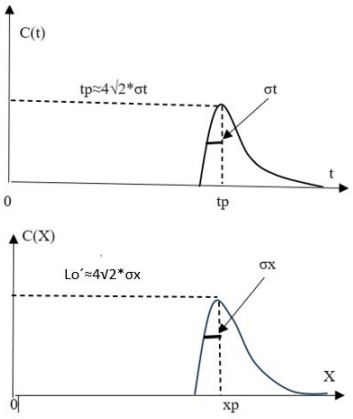

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Figure 3: Definition of $4\sqrt{2}*\sigma x$ from 0 to only *one space variance*

b) "Complete Mixing" Condition for Transverse Transport as Function of Transverse Variance

To establish when the transverse axis transport reach the cross section homogeneously of solute tube, a similar analysis must be performed to determine how many times the transverse spatial variance, σ_y, is in the width, Wo, for the same distance Lo´. Figure 4.

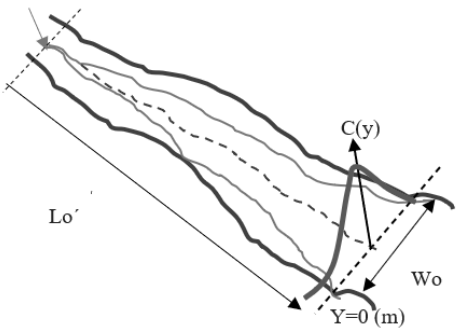

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Figure 4: Curve C(y) in Wo, at distance Lo´

The Gaussian expression in terms of the transverse spatial variance for this case is, with Cp equal in C(X) and C(Y), since $t \approx 4\sqrt{2}*\sigma t$ for both distributions , as follows

$$\boldsymbol{C(y)i \approx Cp * e^{-\frac{(y-\frac{W}{2})^2}{2*\sigma_y^2}}} \quad (21)$$

The function C(t) in this case corresponds to the inflection points of the curve.

$$\boldsymbol{C(t)i \approx 0.608 * Cp} \quad (22)$$

Therefore, eq. (21) would be put like this:

$$\boldsymbol{\frac{Cp}{C8)i} \approx e^{+\frac{(y-\frac{W}{2})^2}{2*\sigma_y^2}}} \quad (23)$$

Rearranging:

$$\frac{1}{0.608} \approx 1.64 \approx e^{+\frac{(y-\frac{W}{2})^2}{2*\sigma_y^2}} \quad (24)$$

And then, with y=0:

$$Ln|1.64| \approx 0.50 \approx \frac{\left(\frac{W}{2}\right)^2}{2*\sigma_y^2} \approx \frac{W^2}{8*\sigma_y^2} \quad (25)$$

And then:

$$\sigma_y \approx \frac{W}{2} \quad (26)$$

Then, concurrently with eq. (3), the tracer plume, when $\Phi \approx 0.38$, transversely occupies half of the plume width. Figure 5.

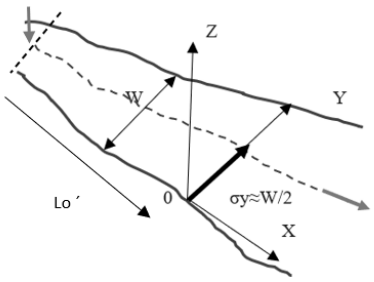


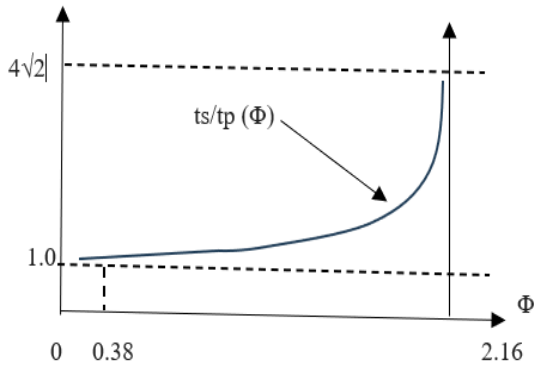
Figure 5: Occupation of ½ Flow Width by Diffusion transverse variance

Therefore, dividing the two displacements, the longitudinal and the transversal, we have:

$$\frac{\sigma_x}{\sigma_y} \sim \frac{4\sqrt{2}}{1} \approx 4\sqrt{2} \quad (27)$$

c) *Quantitative Description of this Dynamic to Find the Ratio of Centroid Time and Peak Time*

The author have already developed a successful approach for calculating the centroid-to-peak time ratio, "t_s/t_p," based on thermodynamic considerations, [27] as shown in Figure 5.



Source: Author

Figure 5: Curve of the ts/tp ratio as a function of Φ(t)

When $\Phi \approx 2.16$, the ts/tp ratio is maximum, close to $4\sqrt{2}$, which is the maximum allowed by the homogeneously distributed mass. For $\Phi < 0.38$, it asymptotically approaches 1.0, i.e., there is no delay in the solute centroid when electrostatic interactions between its particles cease. The approximate equation for this trend is:

$$\frac{ts}{tp} \approx 0.85 * \Phi^{2.2} + 1 \quad (28)$$

A notable value of this calculation is when $\Phi \approx 0.38$, the moment at which the solute changes to the ideal gas condition, and the electrostatic "braking" effect is reduced to a minimum:

$$\frac{ts}{tp} \approx 0.85 * 0.38^{2.2} + 1 \approx 1.10 \quad (29)$$

Which means that the centroid delay is 10%, that is, at the limit of the order of magnitude to not be considered.

d) *Quantitative Description of this Dynamic to Find the Ratio of the Transport Coefficients Σ_x and Σ_y.*

Now, based on results described in 4.2, it is interesting to find the relationship "σ_x/σ_y", which corresponding curve is as shown in Figure 6.

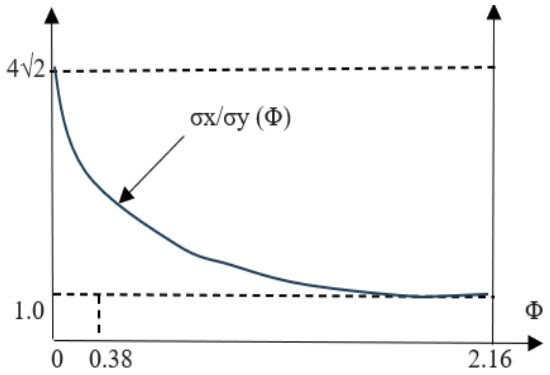


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Figure 6: Curve of the σ_x/σ_y ratio as a function of Φ(t)

A more detailed representation, including notable modeling points, is shown in Figure 7.

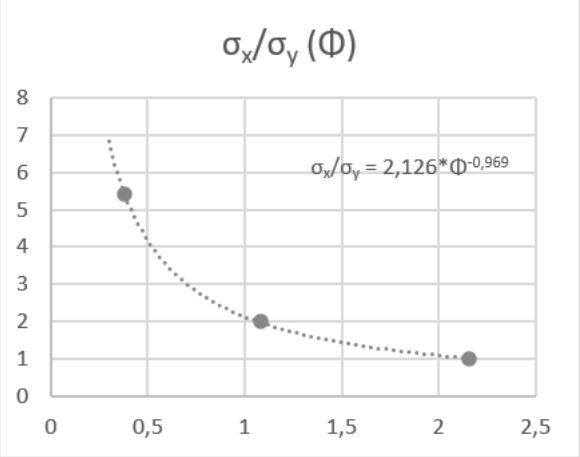

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Figure 7: Detailed Curve of the ratio σx/σy as a function of Φ(t)

The approximate equation for this trend is:

$$\frac{\sigma_x}{\sigma_y} \approx \frac{2.126}{\Phi^{0.969}} \tag{30}$$

The notable points here are: For Φ≈2.16, at the beginning of the process, the two variances are practically equal, and σx/σy≈1, given that the bias imposed by the advection shear effect is just beginning. For later events, when Φ≈0.38, the two values progressively diverges to infinity.For this reason, as a practical limit of the expansion of the function, it is taken no longer to 0.38. Note that this limit is the one of interest, since up to this point, the "Mixing Length" is obtained.

Therefore, the Gaussian ratio of the longitudinal and transverse transport coefficients will be:

$$\frac{\sigma_x}{\sigma_y} \approx \sqrt{\frac{E}{\varepsilon y}} \tag{31}$$

And therefore:

$$\frac{E}{\epsilon y} \approx \left(\frac{\sigma_x}{\sigma_y}\right)^2 \tag{32}$$

Normally the longitudinal coefficient, E, is known, then the transverse coefficient will be:

$$\boldsymbol{\varepsilon y} \approx \frac{E}{\left(\frac{\sigma_x}{\sigma_y}\right)^2} \tag{33}$$

This value of εy must be contrasted with the one calculated from the Elder corrected eq. (19), which is considered an acceptable standard for the channel under study.

V. Practical Application of the Method to Real Channels in Colombia and USA

a) Upper Guavio River, Colombia in 2001

For this study, we consider saline tracer (NaCl) experiments conducted by the Universidad de los Andes in Bogotá in 2001 on the upper Guavio River, a mountain , very roughness river near the town of Arbelaez in the center of the country. [28] Figure 8.

Source: Author

Figure 8: View of Rio Guavio, near Arbelaez. Colombia

The data of this stream experiment is in Table 1.

Table 1: Experimental data at Rio Guavio

Date: June 17, 2001. 2n station curve.
2ond curve length: X = 98.1 (m)
Width: W ≈ 10.0 (m)
Depth: H ≈ 0.25 (m)
Hydraulic radius: R≈0.22 (m)
Slope: S ≈ 0.045
Cross-sectional area: Ayz ≈ 2.3 (m2)
Roughness (Manning): n ≈ 0.32
Flow rate: Q ≈ 0.550 (m3/s)
Average velocity: U ≈ 0.24 (m/s)
Mass (NaCl): M ≈ 12233.0 (g)
Peak time: tp ≈ 410.0 (s)
State function: Φ ≈ 0.55
Longitudinal coefficient: E ≈ 0.77 (m2/s).

Source: Author

The experimental tracer curve and its model, using equation (9), for that experiment at the second station, are shown in Figure 9.

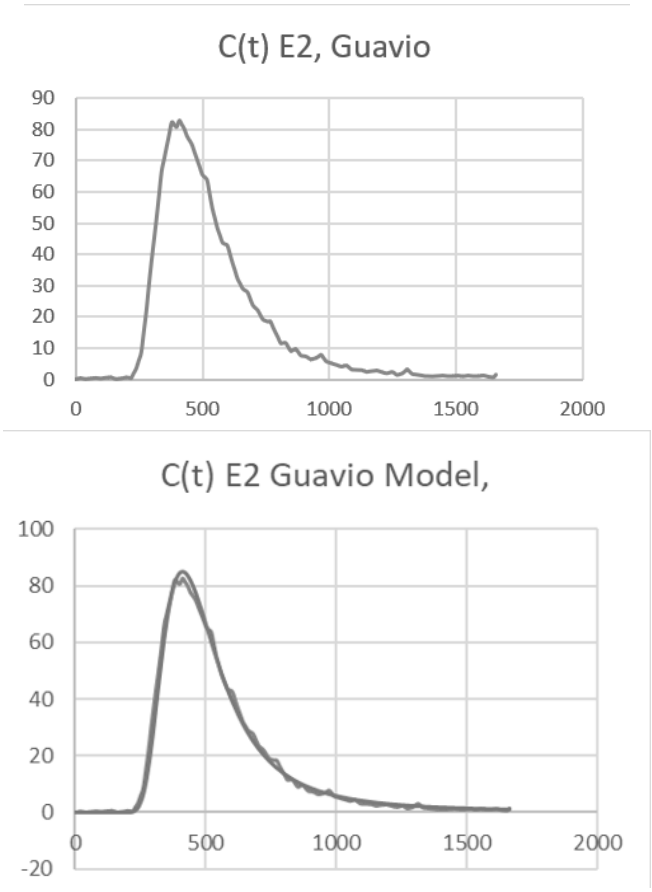

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Figure 9: Experimental curve (broken) and superimposed model (soft), using equation (10)

As can be seen at a distance of X1=98.1 (m) and with a State Function of $\Phi 1 \approx 0.55$, does not yet reach the condition of complete mixing, which occurs at $\Phi \approx 0.38$, then the unknown distance, Lo, must be estimated approximately with the eq. (7):

$$\frac{\Phi 1}{\Phi 2} \approx \frac{\sqrt{X2}}{\sqrt{X1}} \tag{34}$$

Then:

$$\sqrt{X2} \approx \sqrt{98.1} * \left(\frac{0.55}{0.38}\right) \approx 14.33 \tag{35}$$

So:

$$X2 \approx Lo' \approx 206.3\ (m) \tag{36}$$

Now, ratio σ_x/σ_y, eq. (30) is then calculated for $\Phi \approx 0.38$

$$\frac{\sigma_x}{\sigma_y} \approx \frac{2.126}{(0.38)^{0.969}} \approx 5.43 \tag{37}$$

And the transverse transport coefficient, εy, is as in eq. (33):

$$\varepsilon y \approx \frac{E}{\left(\frac{\sigma_x}{\sigma_y}\right)^2} \approx \frac{0.77}{5.43^2} \approx \frac{0.77}{29.5} \approx 0.026\ \left(\frac{m2}{s}\right) \tag{38}$$

This Coefficient is verified against the value obtained by Elder:

$$\varepsilon y \approx 0.6 * 0.25 * \sqrt{0.25 * 9.83 * 0.045} \approx 0.050\ \left(\frac{m2}{s}\right) \tag{39}$$

The ratio of the two results are 1.92, then, of the same order of magnitude, and are accepted as valid verification. The mixing length Lo, eq. (2), is then:

$$Lo \approx \frac{0.1 * 0.24 * 10^2}{0.026} \approx 92.3(m) \tag{40}$$

Comparing with Lo´ calculated with eq. (7) , it is noted that Lo´>Lo and it is accepted that With a central injection (k=0.1) the dispersion covers the width of the channel, but as Lo´ is greater, the solute does not yet have a homogeneous distribution in its volume. Although the transverse diffusion coefficient has been calculated with a good approximation to the reference (Elder-Fischer), since there is no strict control over the exact injection, the multiplier "k" may vary. In this case, the Lo´ figure can be considered more precise since it does not depend on this factor.

b) Rio Bogota, Colombia in 2024

The Bogota River near the flower farms in the capital is a small to medium-sized plain river with a gentle gradient. In this day were used fluorescent tracer (RWT). Figure 10.

Source: Author

Figure 10: Bogota River, near capital, in Colombia.

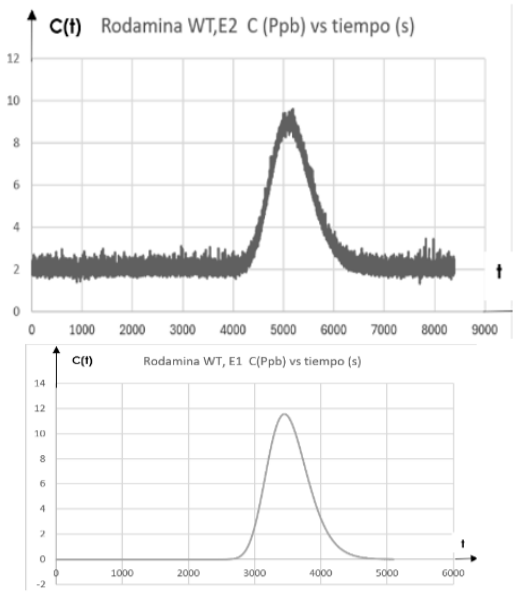
The river experimental data on that day were in Table 2.

Table 2: Experimental data at Rio Bogota

Date: September 5, 2024. 2ond station curve
2ond curve length: X = 3515.0 (m)
Width: W ≈ 20.0 (m)
Depth: H ≈ 2.3 (m)
Hydraulic radius: R≈1.58 (m)
Slope: S ≈ 0.0006
Cross-sectional area: Ayz ≈ 38.8 (m2)
Roughness (Manning): n ≈ 0.025
Flow rate: Q ≈ 26.8 (m3/s)
Average velocity: U ≈ 0.69 (m/s)
Mass (RWT): M ≈ 160.0 (g)
Peak time Second curve: tp ≈ 5097.0 (s)
State function: Φ ≈ 0.167
Longitudinal coefficient: E ≈ 7.25 (m2/s).

Source: Author

The experimental tracer curve and its model, eq. (10), for that experiment at the second station, are shown in Figure 11.



Source: Author

Figure 11: Experimental curve (red) and superimposed model (gray)

As can be seen, the "Complete Mixing" condition for Dispersion was reached at an earlier point, since Φ<0.38, therefore equation (7) must be applied to calculate approximately the distance X1 at which it occurred with $\Phi_1 \approx 0.38$:

$$\sqrt{X1} \approx \left(\frac{\Phi 2}{\Phi 1}\right) * \sqrt{X2} \qquad (41)$$

And then:

$$\sqrt{X1} \approx \left(\frac{0.167}{0.38}\right) * \sqrt{3515} \approx 26.1\ (m^{\frac{1}{2}}) \qquad (42)$$

And therefore, X1≈Lo´≈681.0 (m)
Now, eq. (30) is then calculated for Φ≈0.38:

$$\frac{\sigma_x}{\sigma_y} \approx \frac{2.126}{(0.38)^{0.969}} \approx 5.43 \qquad (43)$$

And the transverse transport coefficient, εy, is in eq. (33):

$$\varepsilon y \approx \frac{E}{\left(\frac{\sigma_x}{\sigma_y}\right)^2} \approx \frac{7.26}{5.43^2} \approx \frac{7.26}{29.5} \approx 0.25\ \left(\frac{m2}{s}\right) \qquad (44)$$

It is verified against the value obtained by Elder-Fischer:

$$\varepsilon y \approx 0.6 * 2.3 * \sqrt{2.3 * 9.83 * 0.0006} \approx 0.160\ \left(\frac{m2}{s}\right) \qquad (45)$$

The ratio of the two results are 1.56, then, of the same order of magnitude, and are accepted as valid verification.

$$Lo \approx \frac{0.1 * 0.69 * 20^2}{0.25} \approx 662.4\ (m) \qquad (46)$$

Comparing with Lo´, calculated with equation (7), it is noted that Lo´≈ Lo (same order) and it is accepted that the calculation on the width of the channel is equivalent to the criterion of homogeneous distribution of the tracer on the solute current tube.

c) Caltech Channel, USA in 1966

A third example is documented, a tracer experiment carried out by H. B. Fischer [29] on the 40 (m) calibrated channel of the W. M. Keck Laboratory at Caltech, in 1966. In this experiment (Series 2700), Fischer injected NaCl as a tracer, measuring two sequential curves. The objective of the experiment was to test Elder's diffusion theory. Figure 12.

Source : [3]

Figure 12: W.M. Keck 40 (m) channel in Caltech. USA

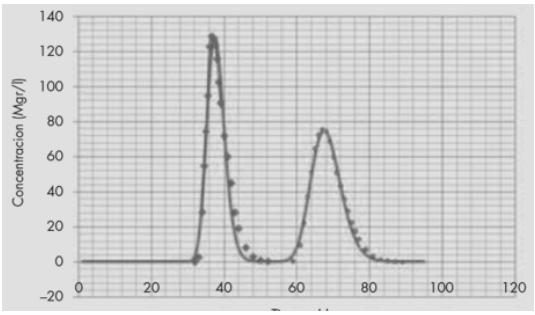
The channel experimental data on that day were in Table 3:

Table 3: Experimental data at Caltech channel

Date: 1966. 2ond station curve.
2nd curve length: X = 25.06 (m)
Width: W ≈ 1.09 (m)
Depth: H ≈ 0.128 (m)
Hydraulic radius: R≈0.104 (m)
Slope: S ≈ 0.0002
Cross-sectional area: Ayz ≈ 0.14 (m2)
Roughness (Manning): n ≈ 0.009
Flow rate: Q ≈ 0.053 (m3/s)
Average velocity: U ≈ 0.372 (m/s)
Mass (NaCl): M ≈ 40.5 (g)
Peak time 2ond curve: tp ≈ 67.4 (s)
State function 2ond curve: $\Phi \approx 0.130$
Longitudinal coefficient: E ≈ 0.0169 (m2/s).

Source: Author

The experimental (dotted lines) two tracer curves and the models (thick continuous lines), are shown in Figure 13.



Source: Author

Figure 13: Experimental curves (dotted) and superimposed model (thick continuous line)

As can be seen, the "Complete Mixing" condition for Dispersion was reached at an earlier point, since $\Phi<0.38$, therefore eq. (7) must be applied to calculate approximately the distance at which it occurred, with X2≈25.06 (m), and $\Phi 2 \approx 0.130$. It is necessary that $\Phi 1 \approx 0.38$ as explained.

$$\sqrt{X1} \approx \left(\frac{\Phi 2}{\Phi 1}\right) * \sqrt{X2} \tag{47}$$

And then:

$$\sqrt{X1} \approx \left(\frac{0.130}{0.38}\right) * \sqrt{25.06} \approx 1.71\ (m^{\frac{1}{2}}) \tag{48}$$

And therefore, X1≈Lo´ ≈ 2.93 (m)
Now, eq. (30) is then calculated for $\Phi \approx 0.38$

$$\frac{\sigma_x}{\sigma_y} \approx \frac{2.126}{(0.38)^{0.969}} \approx 5.43 \tag{49}$$

And the transverse transport coefficient, εy, is in eq. (33):

$$\varepsilon y \approx \frac{E}{\left(\frac{\sigma_x}{\sigma_y}\right)^2} \approx \frac{0.0169}{5.43^2} \approx \frac{0.0169}{29.5} \approx 0.0006\ (\frac{m2}{s}) \tag{50}$$

It is verified against the value obtained by Elder:

$$\varepsilon y \approx 0.6 * 0.128 * \sqrt{0.128 * 9.83 * 0.0002} \approx 0.00122\ (\frac{m2}{s}) \tag{51}$$

The ratio of the two results are 4.92, not so convergent to unit, but of the same order of magnitude, and are accepted as valid verification.

The mixing length Lo, eq. (2), is:

$$Lo \approx \frac{0.1*0.372*1.09^2}{0.0006} \approx 73.7\ (m) \tag{52}$$

The two notable distances, Lo and Lo', differ greatly in their values, indicating that longitudinal dispersion achieves the mixing effect first, rather than transverse diffusion, which has an exaggeratedly high value for the special scope of the channel, indicating that probably in artificial channels, with very small Longitudinal transport coefficient, the indicated method to establish "Complete Mix" is the Lo´ calculation.

VI. Results and Discussions

1. This article develops criteria to estimate when a flow reaches the "Complete Mixing" condition. When using the classic Rutherford formula, the transverse diffusion coefficient is calculated from the ratio of longitudinal and transverse variances, using a nonlinear distribution function of Φ, and the value of the longitudinal dispersion coefficient. The values of these calculations are convergent with those found by the Elder-Fischer formula. The alternative criterion is based on finding the distance from the tracer at which $\Phi \approx 0.38$, and the solute is considered homogeneously distributed in the volume covered by the tracer.
2. The first criterion estimates that the tracer fills the channel width, while the second does not.
3. In real streams, the two criteria can sometimes converge, and sometimes not. In very large rivers (with very large widths), where the "mixing lengths" calculated using the classic formula are very long, the other criterion should be preferred, since the interest is often to determine the advection-dispersion characteristics at a certain intermediate point (not across the entire width).
4. To characterize the evolution of the conservative solute in the flow, a state function Φ, is documented, which describes the different notable moments analyzed here.
5. To verify whether this value of εy is consistent with Elder's classic calculation, taken as a reference, the method is applied to a real field experiment.

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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.

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.

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:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

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."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection.

Segment draft and final research paper: You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

Written material: You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

Criterion for Grading a Research Paper (Compilation) by Global Journals

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals.

Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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