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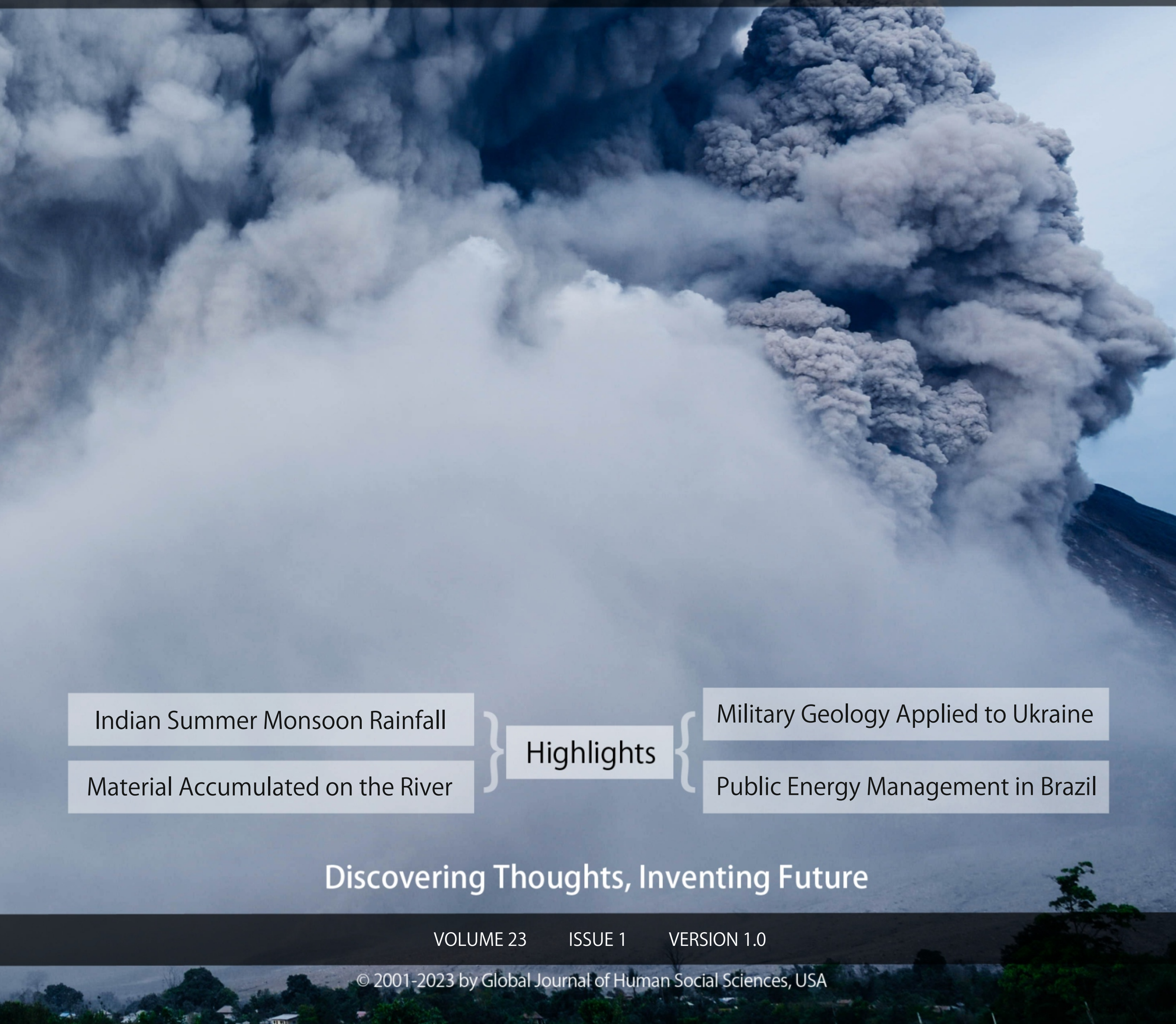

Highlights

- Indian Summer Monsoon Rainfall
- Material Accumulated on the River
- Military Geology Applied to Ukraine
- Public Energy Management in Brazil

Discovering Thoughts, Inventing Future

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Public Energy Management in Brazil: Decision Analysis and Machine Learning

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Abstract- The analyzes carried out by artificial intelligence must start from a complete and integrated data structure, which is classified and grouped with the intention of synergistically producing mental and predictive captures. In this perspective, the objective of this study is to analyze the possibility of contribution of artificial intelligence in guiding decision-making in the public planning of sustainable electrical matrices. The methodological procedures of this investigation, built a structure of analysis of electricity sources, based on the economic, social, environmental and technological dimensions; as well as a sectoral analysis structure of energy sustainability indicators, supported by linear correlations of an economic, social, environmental and political nature. The planning of electrical matrices, according to the inferences of this investigation, can use artificial intelligence as a strategic guide for decisions, as long as they are based on analysis structures focused on the strategic use of electricity sources and the use of sectoral and multidimensional indicators.

Keywords: planning; sustainability; electricity.

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Public Energy Management in Brazil: Decision Analysis and Machine Learning

Fabricio Quadros Borges [α], Bruno Alencar da Costa [σ], Inaldo de Sousa Sampaio Filho [ρ], Marlis Elena Ramírez Requelme [Ѡ] & João Paulo Abreu Almeida[¥]

Abstract- The analyzes carried out by artificial intelligence must start from a complete and integrated data structure, which is classified and grouped with the intention of synergistically producing mental and predictive captures. In this perspective, the objective of this study is to analyze the possibility of contribution of artificial intelligence in guiding decision-making in the public planning of sustainable electrical matrices. The methodological procedures of this investigation, built a structure of analysis of electricity sources, based on the economic, social, environmental and technological dimensions; as well as a sectoral analysis structure of energy sustainability indicators, supported by linear correlations of an economic, social, environmental and political nature. The planning of electrical matrices, according to the inferences of this investigation, can use artificial intelligence as a strategic guide for decisions, as long as they are based on analysis structures focused on the strategic use of electricity sources and the use of sectoral and multidimensional indicators. This investigation constitutes an original contribution insofar as it discusses the possibilities of connections between artificial intelligence and the construction of electrical matrices, from the perspective of improving the decision-making process in Brazilian public planning. The discussion about these connections helps to raise subsidies for machine learning to process and develop methodologies, based on algorithms, that automate the construction of decision analysis models in the planning and sustainable construction of the use of electricity.

Keywords: planning; sustainability; electricity.

I. Introduction

Studies on A.I. emerged in the 1950s, through scientists Herbert Simon and Allen Newell, who created the first artificial intelligence laboratory at Carnegie Mellon University (Santos, 2021). The advances in Artificial Intelligence (A.I.) bring important reflections on how this field of knowledge will affect human routine. The Web Summit 2018, one of the largest technology and innovation conferences in the world, points to a solid and irreversible path towards this technology. The AI branch seeks, through computational symbols, to elaborate mechanisms that simulate the human capacity to be intelligent, which already demonstrates effects in several areas of knowledge; the advances of these studies represent improvements in the application of available resources to the extent that they can strategically guide the decision-making process in organizations (Colson, 2019; Santos, 2021).

In view of this panorama, there is a hope that A.I. it could also help public planning in the electricity sector, insofar as it could support public managers to design more sustainable electrical systems through the optimization of resources, help motivate individual or organizational consumption patterns. It is envisaged that this possibility of contribution is based on the use of analytical models capable of accurately examining the ideal combinations of the use of energy sources in alignment with the specificities of each region and effectively favoring the improvement of the standard of living of the populations. Energy generation sources have advantages and disadvantages that need to be precisely identified and examined from the normative framework of sustainable development.

The energy issue becomes increasingly important in the planning agenda of both developed and emerging countries (Campos *et al*., 2017). In this perspective, the process of economic expansion of a country is linked to an increase in the supply of energy generated by investments applied in the electricity sector and, therefore, increased consumption (Reis *et al*. 2012; Narayan *et al.,* 2017). The role of electricity through the electricity sector is of fundamental importance within a nation, as it moves all sectors of economic activity within society (Saidi *et al.,* 2017). In view of this, this input has been treated as a good of a strategic nature that involves economic, social, environmental, political and technological dimensions (EIA, 2018).

The conditions of availability of electric energy in quantity, quality and costs determine the ability of societies to ensure a certain standard of living through targeted investments, hence the peremptory need to

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improve the decision-making process along with the construction of electrical matrices, through of machine learning. Machine learning, a branch of AI, is a methodology for examining information that automates the creation of analysis models, supported by the idea that systems can learn from data and identify patterns (Colson, 2019; Desordi & Bona, 2020). In reality, it is human beings who make decisions, systems only add value to information by transforming it into knowledge that may or may not be used by managers. Thus, decision-making in environments with multiple uncertain and imprecise information, and the extraction of knowledge from varied and complex databases for the benefit of society, could have its risks severely reduced. In this context, this article asks: how can machine learning guide the public management of electricity in Brazil in a sustainable way? The implementation of A.I. in public planning of energy matrices is an inexorable step for governmental organizations in the Brazilian electricity sector to transform their processes, prioritizing effectiveness and transparency.

Desordi and Bona (2020), developed investigations that analyzed how the use of A.I. can contribute to the realization of the principle of efficiency in Public Administration. Figueiredo and Cabral (2020), especially investigated the insertion of A.I. in the activities carried out by the Public Administration, observing the principles of good administration and the implementation of fundamental rights. Research carried out by Marques (2020) developed an approach focused on the limits and possibilities of using artificial intelligence in the context of public administration. Araujo et al. (2020) carried out an investigation that particularly addressed the impact of administrative decisions made based on algorithms from large databases in the scope of Public Administration. But it was through Valle's investigations (2020), that several conceptualizations on artificial intelligence modeling, especially machine learning, and the functions it can play in public organizations became available.

What is known about the subject is that AI can strategically contribute to the field of Public Administration (Colson, 2019; Desordi & Bona, 2020; Marques, 2020; Araújo *et al.,* 2020 & Valle, 2020). What is not known is how AI can contribute to the public planning of sustainable electricity matrices, in order to consider the potential and borderline specificities of the sources used, as well as, in order to consider significant relationships between electric energy variables and development variables, without neglecting the interactionist sociological aspects. The notion of intelligence used ignores the fact central to interactionist sociology that there is interaction with other human beings in social contexts (Dreyfus & Dreyfus, 1986). This article fits into this context insofar as it seeks to meet these demands through an analysis of the possibility of artificial intelligence contributing to guiding decision-making in public planning of sustainable electricity matrices, in order to consider the specificities of sources of electricity generation, the strategic relationships between energy and development and the interactionist contribution of sociology.

The study brings as learning a contribution in a practical scope, by providing opportunities for a debate that seeks to discuss possibilities of connections between artificial intelligence and the construction of electrical matrices, from the perspective of improving the decision-making process in Brazilian public planning. Specifically, the investigation facilitates this debate through the elaboration of structures for the analysis of electricity sources, based on economic, social, environmental and technological dimensions; as well as, through a structure of sectoral analysis of energy sustainability indicators, supported by linear correlations of economic, social, environmental and political nature. This discussion is relevant insofar as the preliminary elaboration of these multiple structures of dimensional analysis comprises a condition for the precise survey of subsidies for machine learning to process and elaborate methodologies, based on algorithms, that automate the construction of decision-making models in public energy management in Brazil.

II. Methodological Strategy

This investigation is categorized in terms of ends and means, according to Vergara's grouping (2016). As for the purposes, it is considered exploratory, insofar as it involves a survey of subsidies that propose to analyze realities that stimulate the understanding of the connections between A.I. and the planning of sustainable electrical matrices. And as for its means, it is considered bibliographic and documental, insofar as it uses a survey of materials and documents from bodies linked to the Brazilian electricity sector.

The methodology was strategically divided into three tasks: data collection, data organization and data analysis.

a) Data Collection Procedure

Initially, it is highlighted that the variables used in the construction of the indicators were: amount of electricity consumed; Gross Domestic Product; amount invested in electricity; average electricity tariff; average income of the worker; number of jobs generated; energy efficiency and amount of polluting gas emissions. The period of data collection with the variables was between 2008 and 2018. The spatial collection of this data was the State of Pará, chosen for its characteristic of being an exporter of electricity and for being a place of socio-environmental impacts resulting from the process of generating energy from a water source. The sources used in the research for the elaboration of the indicators were: National Energy Balance (BEN); Useful Energy Balance (BEU); National Household Survey (PNAD);

National Electric Energy Agency (Aneel), Secretary of Planning, Budget and Finance of the State of Pará (Sepof); Brazilian Institute of Geography and Statistics (IBGE); Interunion Department of Statistics and Socioeconomic Studies (Dieese), General Register of Employed and Unemployed People (Caged); National Institute of Energy Efficiency (INEE); Ministry of Mines and Energy (MME); National System Operator (ONS); and Energy Equatorial Group (EEG).

b) Data Organization Procedure

In this study, two analysis structures were constructed. The first refers to the use of electrical energy sources, based on the economic, social, environmental and technological dimensions. The second structure of analysis, pertinent to the use of sectoral indicators of energy sustainability, supported by linear correlations of an economic, social, environmental and political nature. In the process of elaborating the structure of analysis pertinent to the use of electric energy sources, supported by the economic, social, environmental and technological dimensions, emphasis was placed on the identification of potentialities and limitations in the use of electricity sources: water, biomass, solar, wind and nuclear. The intention was to provide a critical examination regarding the insertion possibilities and proportion of these sources in the electrical matrix. The dimensions used in this analysis were economic, social, environmental and technological, as they better characterize the environment of sustainable development. It is important to point out that this critical examination of electrical energy sources must respect the locational specificities, as each region presents strategic potential and substantial limitations regarding the production and use of the electrical input. In the elaboration of the sectorial analysis structure of energy sustainability indicators, supported by linear correlations, the correlation sought as a result a coefficient that quantified the degree of correlation called Pearson's coefficient (p) (Chen & Popovic, 2002).

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2} \cdot \sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}},$$

Where: x1 , x2 , ..., xn and y1 , y2 , ..., yn comprise the measured values of both variables. And the following equations are the arithmetic means of these variables:

$$\bar{x} = \frac{1}{n} \cdot \sum_{i=1}^{n} x_i \quad \text{e} \quad \bar{y} = \frac{1}{n} \cdot \sum_{i=1}^{n} y_i$$

In this study, the linear correlations observed in each of the dimensions, across sectors, were described and analyzed with regard to their importance, representativeness and unit of measurement used. The software used for calculation was the Statistical Package for the Social Sciences (SPSS). At a later moment, the variables were organized according to the dimensions: economic, social, environmental and political, which built the energy sustainability indicators, and from each sector of activity, which made up the energy sustainability indexes. In calculating the indicators, we proceeded from a weighted average composed of the result of the calculation of the composite variables. In calculating the composite variables, the calculation adopted two variables: the first referring to development, and the other referring to the energy environment. The results of the correlations, which indicated the use of certain relationships of variables to the detriment of others, were due to the specificities of the data referring to the State of Pará, between 2010 and 2019, used here to merely operate the calculation and consequent indication of the relationships of variables across sectors of economic activity. Thus, depending on the state or region and based on their respective locational specificities, the relationships of variables indicated by the software used can naturally be different.

c) Data Analysis Procedures

The analysis structures of electricity generation sources and energy sustainability indicators, built in the study, were examined with the intention of raising subsidies in the construction of decision-making standards along with the process of elaboration of the electric matrix. The purpose of this examination is to verify the possibility that the A.I. build analytical models capable of evaluating, with precision, potentialities, limitations and impacts of the individual or combined use of electric energy sources in certain regions and based on the productive profile of each sector of economic activity. In the practical field, the possibility of effectively demonstrating the connections between public planning of electrical matrices and AI lies in the construction of Algorithms. In this sense, Algorithms applied to AI would be guidelines to be learned and followed by a machine.

In this study, these guidelines that would feed the Algorithms would be assigned precisely from the result of the analysis of the structure of electricity generation sources and the structure of energy sustainability indicators. In reality, Algorithms would just be a mathematical way of demonstrating a structured process for executing a task. In other words, they would be principles and flows of sequential analysis that guide the decision-making process in the electricity sector. In this methodological strategy, it was intended to present only a first approximation to the effort to build Algorithms at the service of AI, through the basic phases of an Algorithm's performance: input, processing and output, in the context of sustainable electrical matrices.

III. Public Electricity Management and Machine Learning

Public planning is technically evidenced through the events of the budget cycle, which, in turn, is composed of the phases in which public budget preparation and execution activities occur (Giacomoni, 2010). However, the debate about public planning has frequently promoted mentions, especially, of the ability of managers to achieve qualitative results in the use of public resources applied to the territory; among them, the influence of group ideologies that interfere with more decision-making power, through correlations of forces with various ramifications, such as energy (Mafra & Silva, 2004; Schultz, 2016; Dagnino *et al*., 2016).

In the environment of the Brazilian energy sector, planning is developed through public policies, which generally intend to demonstrate that investments aim at economic growth and improvement of the population's living conditions. In this process, there are strategic aspects ranging from the choice of energy generation sources to the reflections of the use of this energy in different sectors of a country's economy (Borges 2012; Cornescu & Adam, 2014). The projection of the composition of these available energy sources, which should be directed to meeting the energy demands in a given state, region or country, is called the energy matrix.

The energy matrix is the description of all the generation and consumption of energy, of a certain spatial cut, broken down in terms of production sources and consumption sectors for a future situation; thus, when all the generation and consumption of a country or region is described for a current situation, it is called energy balance (Borges & Zouain, 2010; Reis *et al*., 2012). According to EPE (2020), the national energy matrix is currently prepared by the Energy Research Company. The electrical matrix, in turn, is inserted in the energy matrix and represents the disposition of the different forms, specifically, of electricity, made available to the productive processes in a determined spatial context, involving its sources of generation and use (Tolmasquim *et al*., 2007; Reis *et al.,* 2012). The observance of this arrangement of sources for the generation of electricity assumes a strategic role insofar as the projections verified in a given electrical matrix, value the facilitation of forms of access to the population. Electric energy sources comprise essential inputs for sustainable development (Goldemberg & Moreira, 2005) and the understanding of this normative reference is essential for the construction of an electrical matrix.

The conceptualization of sustainable development assumes a new world order, which results in a redistribution of powers that ignores the correlations of forces that are active in the world market, and the interests of industrialized nations in maintaining a position of advantage in the international panorama (Borges *et al.*, 2017; Silva *et al.,* 2018). However, the definition of this normative reference is steeped in contradictions, insofar as the difficulty lies in the fact that economic interests are not submissive to social and environmental interests. Sustainable development aims to promote sustainability. Sustainability is linked to an activity that can be maintained for an indefinite period of time, so as not to reach its exhaustion, despite the unforeseen events that may occur during this period, based on relatively consistent economic, social and environmental bases (Glavic & Lukman, 2007; Marzall, 1999; Bursztyn, 2008; Borges, 2012). According to Camargo *et al*. (2004), Bursztyn (2008) and Borges (2015), sustainability would then be defined as the ability to sustain socioeconomic and environmental conditions that promote the fulfillment of human needs in a balanced way and that occurs through decision-making.

According to Robbins (2010), decision making comprises an occurrence in reaction to a problem and a problem exists when there is a discrepancy between the current state of affairs and its desirable state. In the theoretical framework, decision-making comprises the process of deciding on something and involves selecting an action option from two or more possible alternatives; and in this process there would be at least three components that apply to the public environment and that need to be verified by the observer who wants to carry out investigations on the decision-making process in this area. They are: technology; rules and norms; and decision-making style (Silva, 2013). Regardless of its components, decision-making in public planning shows an environment of frequent slowness due to excessive bureaucracy (Pacheco & Mattos, 2014). In the decision-making process, it is important to highlight that it constitutes an error-prone activity, as it will be affected by the personal characteristics and perception of the decision-maker (Maximiano 2009; Robbins, 2010). In this perspective, more impulsive decision-making and less information processing threatens decision-making processes. In the modern context, decision-making carries cognitive biases and these biases interfere with our decision-making in ways that move away from rational objectivity (Certo, 2005, Colson, 2019). It is precisely there that lies the advent of a new phase of evolution in the decision-making environment, Artificial Intelligence. The term A.I. it is a sub-area of computer science and is used to

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designate the set of computational techniques, devices and algorithms, in addition to statistical and mathematical methods capable of reproducing some of the human cognitive abilities; in other words, it is the science and engineering of making intelligent machines, especially intelligent computer programs (Toffoli, 2018; McCarthy, 2018).

AI comprises an area that is related to the ability of computers to perform tasks, in order to contribute to the construction of intelligent entities through computational algorithms (Norvig & Russell, 2021). In this sense, the A.I. it would consist of the artificial reproduction of the ability to obtain and apply different skills and knowledge to solve a given problem, solving it, reasoning and learning from situations (Hartmann & Silva, 2019). In other words, the A.I. It is a set of instructions and rules that form the algorithm, used in series, to process information and solve problems, with its own method and speed (Corvalán, 2018). The A.I. is already a reality and a great ally of public planning, thanks to the agility and time savings provided by the verification and crossing of data, where it creates possibilities beyond human capacity, offering public bodies elements that could go unnoticed in the analyzes commonly carried out by civil servants (Brega, 2012; Desordi & Bona, 2020).

According to the Association for the Advancement of Artificial Intelligence (AAAI), an entity recognized as a reference association, AI has subareas according to their applicability. AAAI has established a division of AI into the following subareas: Research; Machine Learning; Automated Planning; Knowledge Representation; Data Mining and Big Data; Reasoning (Probabilistic or not); Natural Language Processing; Robotics; Agent and Multi-Agent System and Applications (AAAI, 2021). In this perspective, it should be noted that this article especially addresses the Machine Learning subarea, in that it seeks to carry out an inventory of which data would be important to identify relevant patterns for decision-making in the face of electrical matrices.

Machine learning comprises a data analysis method that automates the construction of analytical models, based on the idea that systems can learn from data, identify patterns and make decisions with minimal human intervention (Colson, 2019; Desordi & Bona, 2020). In this dynamic of learning from data and identifying patterns for decision-making, the strategic opportunity of applying AI to public planning of sustainable energy matrices stands out, as analytical models capable of accurately assessing potentialities, limitations and impacts of the individual or combined use of electric energy sources in certain regions and based on the productive profile of each sector of economic activity. The possibility of effectively establishing a clear and objective link between the public planning of electrical matrices and AI lies in the construction of Algorithms. Algorithm comprises a finite sequence of executable actions that aim to obtain a solution to a given problem (Dasgupta et al., 2010). In this perspective, the Algorithms applied to AI are constituted as a sequential set of rules or operations that, applied to a number of data, enable the resolution of problems.

IV. Analysis and Discussion of Results

This section is divided into two parts, namely: analysis of electricity generation and analysis of energy indicators. Analyzes should start from a complete and integrated data structure that needs to be classified and grouped in order to synergistically produce mental captures and predictions; and it is with the intention of favoring a coherent analysis that this didactic division was adopted.

a) *Analysis of Electricity Generation*

This subsection addresses water, biomass, solar, wind and nuclear sources, which will precede the presentation of an analysis structure of electrical energy sources, by dimension.

i. *Water Source:* Based on simple fundamentals - Turbines transform potential energy from reservoirs or water currents into electrical energy. Thus, hydroelectric plants are characterized as renewable energy. However, this source causes serious and extensive impacts on the hydrological cycle and changes in the environment in general. The results record the disappearance of species of fauna and flora, loss of quality of life for the affected populations and threats to the existence of various social groups. The emission of greenhouse gases represents another serious problem caused by large hydroelectric plants, a panorama that does not portray socioeconomic and environmental conditions that promote the fulfillment of human needs in a balanced way (Camargo *et al*., 2004; Bursztyn, 2008; Borges, 2015).

ii. *Biomass:* Is a type of matter that feeds steam power plants for electrical generation from a process of burning elements accumulated in a given ecosystem. Among the most used materials are sugarcane bagasse and woody materials. The burning of biomass causes the release of carbon dioxide into the atmosphere, however, this compound was previously absorbed by the plants that gave rise to the fuel, which provides a zero balance of CO^2 emissions. It is also important to mention that these materials must be close to thermoelectric plants or on strategic routes with easy access, otherwise they may represent disadvantages. In this perspective, the reflections resulting from the use of a certain energy source must be critically observed (Bermann, 2003; Borges 2012; Cornescu & Adam, 2014).

iii. *Sun:* Consists of the use of thermal and light energy captured by solar panels, consisting of photoelectric or photovoltaic cells. This type of energy source is considered clean, renewable and inexhaustible. Solar energy is the one that releases the least CO^2 into the atmosphere, in addition to generating potential for job creation in the solar production chain. The main disadvantages of the solar source are: the high cost of implanting thermosolar panels, which are too expensive to enable the production of electricity on a large scale, and its irregularity in the form of uniform distribution, which requires large collection areas and storage systems. In this analysis bias, according to Borges (2012); Cornescu & Adam (2014), the reflections resulting from the use of a certain source of energy in the environment must be critically observed.

iv. *Wind Power:* Energy derived from a technology that uses the power of wind which, in turn, operates turbines connected to electricity networks. This type of energy source has the advantages of renewable nature, low cost of externalities, does not burn fossil fuels and does not emit polluting gases that cause the greenhouse effect. Among the disadvantages are: the alteration of the landscape when implementing its infrastructure, composed of propellers and towers, the emission of low frequency noise, occasional interference in television sets, the threat to the migratory routes of birds due to the use of large rowed propellers and the unproductiveness of this source in some regions due to the inconstancy of winds, their low intensity and waste of energy in the event of heavy rains.

v. *Nuclear:* It takes place from a thermal base, where the heat produced in the fission to generate water vapor that moves the electricity generation turbines. The advantage of this source lies in its technology, capable of reducing gas emissions in the production of electricity and the climate impacts on the planet caused by the generation of electricity. However, it is relevant to alert defenders of nuclear technology as not emitting greenhouse gases, that if the calculations of the complete process of this type of energy are incorporated, including: uranium mining, transport, uranium enrichment, the subsequent dismantling of the central and the processing and confinement of radioactive waste, this source has disadvantages.

As a methodology that automates the analysis of information, according to Colson (2019), Desordi and Bona (2020), machine learning can favor the development of structures for analyzing electrical energy sources, by dimension, (Table 1) that allow an examination more accurate and ideal for choosing the arrangement of electrical matrix components.

Table 1: Dimensional Analysis of Electricity Generation.

BASE	DIMENSION	GENERAL INFORMATION
WATER	ECONOMIC	Reservoir construction costs and after construction.
	SOCIAL	Generation of jobs in the construction of reservoirs and after construction.
	ENVIRONMENTAL	Emissions of polluting gases.
	TECHNOLOGICAL	Energy density.
BIOMASS	ECONOMIC	Construction costs of a small plant and estimated average cost.
	SOCIAL	Job creation.
	ENVIRONMENTAL	Emissions of polluting gases and capacity for devastation.
	TECHNOLOGICAL	Generation capacity and capacity corresponding to generation.
SUN	ECONOMIC	Installation costs of photovoltaic system and rate of return on investment.
	SOCIAL	Job generation.
	ENVIRONMENTAL	Emissions of polluting gases in the construction of the plant and in its operation.
	TECHNOLOGICAL	Solar radiation potential and infrastructure characteristics.
WIND	ECONOMIC	Cost of installing a wind farm and return on investment.
	SOCIAL	Job generation.
	ENVIRONMENTAL	Emissions of polluting gases in the construction of the plant and in its operation.
	TECHNOLOGICAL	Wind density and characteristics.
NUCLEAR	ECONOMIC	Cost of installing a wind farm and return on investment.
	SOCIAL	Job generation.
	ENVIRONMENTAL	Installation costs and return on investment.
	TECHNOLOGICAL	Energy intensity.

Source: Prepared by the authors (2023).

Decision-making based on the analysis of the use of electrical energy sources, by dimension, is inserted in environments with multiple information (endowed with inaccuracies) and in environments where knowledge is extracted from numerous databases. The high risk in this process may represent high environmental costs or severe socioeconomic damage to the affected populations, due to the results of this decision-making process. In this sense, the A.I. adds: the reduction in the analysis time of the most indicated sources; the solution of problems verified with the demands of society, for the electrical input, whether operational or managerial; and the reduction of rework and failures, frequent in electric energy generation projects observed in Brazil.

b) Analysis of Energy Indicators

The construction process of an electrical matrix must also consider aspects related to economic sectors, since each sector of economic activity reflects investments in electrical energy based on certain peculiarities. These peculiarities can be organized into economic, social, environmental and political dimensions. Below, through Tables 2, 3, 4 and 5, the structures of energy sustainability indicators for each sector of activity are presented, based on linear correlations and from data referring to the State of Pará, during the period 2010 and 2019. Data referring to the state of Pará were used only with the intention of considering its locational specificities.

Table 2: Analysis of electricity sustainability indicators (Agricultural Sector).

AGRICULTURAL SECTOR	ECONOMIC	1) Relationship between the value of the Gross Domestic Product in the agricultural sector and the amount of GWh consumed in the sector. 2) Ratio between the amount invested by the distributor from Pará in electricity in the State and the value of the Gross Domestic Product, per unit of consumption, in the agricultural sector. 3) Relationship between the average electricity tariff charged per kWh in the agricultural sector and the Gross Domestic Product, per unit of consumption, in this sector. 4) Ratio between the amount invested by the distributor from Pará in electricity in the State and no. of consumption units in the sector.
	SOCIAL	1) Relationship between the amount of GWh consumed in the agricultural sector and the average income of Pará workers. 2) Relationship between the amount of GWh consumed in the agricultural sector and the Gini coefficient recorded in the State of Pará.
	ENVIRONMENTAL	1) Relationship between the amount of GWh consumed in the agricultural sector and the energy yield verified in this sector. 2) Relationship between the amount of GWh consumed in the agricultural sector and the accumulated emission of methane gas (CH_4) and carbon gas (CO_2) derived from hydroelectric plants in the state of Pará.
	POLITICAL	1) Relationship between the average electricity tariff charged per kWh in the agricultural sector and the equivalent frequency of interruption per consumer unit in all sectors of the State. 2) Relationship between the amount of GWh consumed in the agricultural sector and the equivalent frequency of interruption per consumer unit in all sectors of the State.

Source: Prepared by the authors (2023).

The structure of indicators shown in Table 3, like the other structures built, was created based on different skills and knowledge, which in a combined way seeks to solve problems related to the use of electrical input, in each sector of activity, in favor of improvement of the standard of living of the population of Pará. In this sense, the A.I. it would consist of the artificial reproduction of this ability to obtain and apply these skills and knowledge to solve a given problem, solving it, reasoning and learning from situations (Hartmann & Silva, 2019). These indicator structures can help build the electrical matrix based on strategies to promote sustainable development.

Table 3: Analysis of electricity sustainability indicators (Industrial Sector).

Sector	Dimension	Indicator
INDUSTRIAL SECTOR	ECONOMIC	1) Relationship between the value of the Gross Domestic Product in the industrial sector and the amount of GWh consumed in the sector.
		2) Relationship between the value of the Gross Domestic Product in the industrial sector and the number of consumption units in the sector.
		3) Relationship between the average electricity tariff charged per kWh in the industrial sector and the Gross Domestic Product in this sector
		4) Relationship between the amount invested by the distributor from Pará in electricity in the State and the number of consumption units in the sector.
	SOCIAL	1) Ratio between the amount invested by the distributor from Pará in electricity in the State and the number of jobs generated in the industrial sector.
		2) Relationship between the amount of kW consumed in the industrial sector and the Gini coefficient recorded in Pará.
		3) Relationship between the number of consumption units in the industrial sector and the recorded Gini coefficient.
	ENVIRONMENTAL	1) Relationship between the amount of GWh consumed in the industrial sector and the energy yield verified in this sector.
		2) Relationship between the amount of GWh consumed in the industrial sector and the accumulated emission of methane gas (CO_2) and carbon gas (CO_2) derived from hydroelectric plants in the state of Pará.
	POLITICAL	1) Relationship between the average electricity tariff charged per kWh in the industrial sector and the equivalent frequency of interruption per consumer unit in all sectors of the State.
		2) Relationship between the number of consumer units in the industrial sector and the equivalent interruption frequency per consumer unit in all sectors.

Source: Prepared by the authors (2023).

In Table 4, there is an effort whose result is based on a statistical tool that seeks to help the decision maker in the process of building the electrical matrix. However, as noted by Toffoli (2018) and McCarthy (2018), what A.I. may add, is something beyond statistical and mathematical methods, that is, the development of an ability to reproduce some of the human cognitive abilities.

AI, according to the author Certo (2005), Maximiano (2009) and Robbins (2010), will enable greater security, trust and control over the interactions necessary for a complex and multidisciplinary process such as the construction of an electrical matrix, since that the traditional decision-making process is prone to errors.

The A.I. aspects that may negatively impact the process of building energy matrices should also be the focus of attention. Moral and ethical questions, as a result of the use of an innovative technology, must be worked on carefully. The dimensions analyzed in an energy matrix are relevant to the strategic areas of sustainability, however, it involves the reality of people and possibilities for improving or not the standard of living. In short, the intention is that the A.I. can be used in a prudent and transparent manner as a technology capable of carrying out an advanced and strategic reading of society's energy demands.

Table 4: Analysis of electricity sustainability indicators (Commercial sector).

Sector	Dimension	Indicator
COMMERCIAL SECTOR	ECONOMIC	1) Relationship between GDP in the sector and the amount of KW consumed in this sector.
		2) Relationship between the amount of GW consumed and the amount invested in electricity in all sectors.
		3) Relationship between the variation in the electricity tariff and the amount invested in electricity in all sectors
	SOCIAL	1) Relationship between the balance of formal jobs in the sector and the amount invested in electricity.
		2) Relationship between average income and the amount of GW consumed.

ENVIRONMENTAL	1) Relation between the variation of energy yield in the sector/Amount of GW consumed. 2) Relationship between the variation in the emission of polluting gases derived from electricity generation and the amount of GW consumed.
POLITICAL	1) Ratio between the variation in the equivalent frequency of interruption per consumer unit and the variation in the tariff charged for electricity. 2) Relationship between the variation in the duration of interruptions per consumer unit and the variation in the tariff charged for electricity in the sector.

Source: Prepared by the authors (2023).

As presented in the methodology of this investigation, the possibility of effectively establishing a direct link between the public planning of electrical matrices and AI is linked to the construction of Algorithms. The Algorithms applied to AI would be principles and rules (guidelines) to be followed by a machine, that is, a structured process for the execution of a task that proposes to guide decision-making in the construction of sustainable electrical matrices. Next, through Chart 6, the foundations for the development of algorithms for Artificial Intelligence in favor of sustainable public management of electric energy are presented.

Table 5: Foundations for the development of algorithms for AI in favor of sustainable public management of electric energy.

STAGE	INPUT STAGE	PROCESSING STAGE	OUTPUT STAGE
GUIDE	INITIAL DATA, THAT IS, POSSIBLE INPUT DATA VALUES OF AN ALGORITHM.	RELATIONS THAT MUST BE SATISFIED TO TRANSFORM INPUT DATA INTO ACCEPTABLE OUTPUT.	RESULTS, THAT IS, DISPLAY OF THE CALCULATION FROM THE INPUT AND PROCESSING PHASES.
INSTRUCTIONS TO ARTIFICIAL INTELLIGENCE	Amount of electricity generated in GW; Amount invested for the generation of electricity; Amount of electricity consumed; Accumulated emission of carbon dioxide gas (CO_2) derived from hydroelectric plants; Energy yield; Electricity generation capacityin Kw; No. of jobs generated from the source of generation; Costs used in generation projects.	Ratio between the amount of electricity generated in GW and the amount invested in generating electricity; Relation between the accumulated emission of carbon dioxide gas (CO_2) derived from hydroelectric plants and the amount of GWh consumed; Relationship between energy yield and amount of GWh consumed; Costs used in generation projects per Kw; Relationship between number of jobs generated from the source of generation and the Amount invested for the generation of electricity through this source.	Ability to meet energy demand; Economic externalities; Social externalities; Environmental externalities; Energy-material flow.

Source: Prepared by the authors (2023).

The results where the generation of electricity and its combined disposition structure in favor of a population, is presented from sustainable bases, must be codified in a programming language. In the coding process, programming language tools must be used. The Java Development Kit (JDK), which is a utility suite that makes it possible to build software systems, and the NetBeans Integrated Development Environment (IDE), which is a program for software development. The technique for building an Algorithm indicated for the electrical matrix environment would be the so-called Narrative Description, which defines what needs to be done and how to do it, that is, it identifies the steps to be followed to achieve sustainable solutions in the electrical matrix environment. The steps related to the use of programming language tools and the complete elaboration of the Algorithms are not an object of observation here.

V. Final Considerations

The possibility that the A.I. building analytical models capable of guiding decision-making in the public planning of sustainable electricity matrices is concrete. In this perspective, this investigation constitutes an original contribution insofar as it discusses the possibility of a connection between artificial intelligence and sustainable public management of electricity in Brazil. The analysis structures elaborated in this investigation, despite being synthetic, aggregate reasonable conditions for evaluating the potentialities, limitations and impacts of the individual or combined use of electric energy sources, in certain regions, and based on the productive profile of each sector of activity.

In this sense, it is up to machine learning, processing and methodological elaboration, based on algorithms, for a precise and transparent examination of information that automates the construction of decision analysis models, supported by the idea that computational systems can learn from data, identify standards, strategically consider locational specifics, and make decisions with minimal human intervention. The discussion about these connections helps to raise subsidies for machine learning to process and develop methodologies, based on algorithms, that automate the construction of decision analysis models in the elaboration of sustainable electrical matrices. The investigation inferred that the possibility of effectively establishing a direct link between the public planning of electrical matrices and AI is linked to the construction of Algorithms. In this perspective, the investigation presented, as an effort to raise subsidies, preliminary stages of construction of Algorithms for AI applied to the decision-making process in the planning of sustainable electrical matrices. This effort constituted a structured proposal of guidelines for machine learning that proposes to contribute to the construction of Algorithms aimed at guiding decision-making in the construction of sustainable electrical matrices.

The research concluded, in this dynamic of analysis, that artificial intelligence can guide decisions in the planning of electrical matrices, as long as they are based on analysis structures focused on the strategic use of electricity sources and on the use of sectoral and multidimensional indicators. These analysis frameworks are able to feed computational analytical models that learn from data, identify patterns and make intelligent decisions with minimal human intervention. Future research on this topic should follow the path of improving the process of building Algorithms for AI applied to the decision-making process, in order to still observe the environment of the sectors of economic activity. The use of energy input in the intricacies of each sector of economic activity presents different reflections on the development process, which represent different intensities in terms of jobs generated, energy efficiency, contribution to GDP, favoring the deconcentration of income, among other relevant and strategic variables in the development process.

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Selected Aspects of Military Geology Applied to Ukraine Barney Paul Popkin Consultant

By Barney Popkin

Introduction- Military decision makers have been considering terrain in their military action plans for thousands of years. By terrain herein is the very broad, detailed, local, and real-time consideration of: water, oil and gas, rock, mineral, forest and other resources; land suitable for tunnels, trenches, and rock walls; topography and landforms in the interest of mobility and ground control; access to safe and protective shelter, stable transportation routes; and other issues. It's clear to the everyday observe that: water is vital; excavatable rocks are easier for tunneling, diggable soils are suitable for trenching, and large rocks are suitable for wall-making than otherwise; flat open or valley lands are easier to conquer than hills or rugged mountains; high ground capture can control surrounding low ground; sand dunes and mud are more difficult to travel over than hard ground; safety behind high, leafy, and dense vegetation is more secure than an open meadow; and seasons and weather may make terrain conditions more or less favorable.

Modern military geology is credit ed to Napoleon Bonaparte whose geologists and engineers left a legacy of maps detailing military advantages and disadvantages of specific terrains in areas of his interest.

GJHSS-B Classification: *DDC Code: 508.8 LCC Code: QH11*

SELECTEDASPECTSOFMILITARYGEOLOGYAPPLIEDTOUKRAINEBARNEYPAULPOPKINCONSULTANT

Strictly as per the compliance and regulations of:

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Introduction

Military decision makers have been considering terrain in their military action plans for thousands of years. By terrain herein is the very broad, detailed, local, and real-time consideration of: water, oil and gas, rock, mineral, forest and other resources; land suitable for tunnels, trenches, and rock walls; topography and landforms in the interest of mobility and ground control; access to safe and protective shelter, stable transportation routes; and other issues. It's clear to the everyday observe that: water is vital; excavatable rocks are easier for tunneling, diggable soils are suitable for trenching, and large rocks are suitable for wall-making than otherwise; flat open or valley lands are easier to conquer than hills or rugged mountains; high ground capture can control surrounding low ground; sand dunes and mud are more difficult to travel over than hard ground; safety behind high, leafy, and dense vegetation is more secure than an open meadow; and seasons and weather may make terrain conditions more or less favorable.

Modern military geology is credited to Napoleon Bonaparte whose geologists and engineers left a legacy of maps detailing military advantages and disadvantages of specific terrains in areas of his interest. He also procured the new decision-making mathematicians to develop systems analysis, also called operations research, to optimize military field logistics. Our Civil War and World War military leaders, and more current modern leaders were and are cognizant of the terrain to fight within and to defend. In the age of satellites, remote sensing, geographic information systems, and computer assisted design, intercontinental missiles, and drones, our knowledge of real-time terrain is rapidly increasingly accurate and useful.

Ukraine has come into the attention for the much of the world since the Russian 2014 invasion and consequent annexation of Ukraine's Crimea, incorporation of Russian-proxy, self-proclaimed, separatist Donetsk and Luhansk Provinces in eastern Ukraine and Russian-invaded Zaporizhzhia and Kherson regions in southeastern Ukraine in 2022, and invasion of Ukraine and annexation of eastern and southeastern Ukraine in 2022.

Location: Ukraine is located in Eastern Europe, surrounded by seven countries and two seas as shown in Figure 1. Note its major rivers and mountains which have military impacts.

Ukraine's complex history is summarized by U.S. CIA Facts (November 2022) and elsewhere, and not needed to be elaborated in this article. The country covers about 603,550 sq km, about 96 percent is land and four percent is water. Ukraine is slightly larger than Texas, or over 3.2 times the size of New England. Its land boundaries border Belarus, Russia, Moldova, Romania, Hungary, Slovakia, and Poland.

Figure 1: Ukraine map showing major cities, parts of the surrounding countries, the Black Sea, and the Sea of Azov (U.S. CIA World Facts, Ukraine, November 2022)

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Climate: Ukraine's generally temperate continental climate is broken by Mediterranean climate on its southern Crimean coast. Precipitation is highest in the west and north, and lesser in the east and southeast of the country. Winters range from cool along the Black Sea to cold inland. Summers are warm throughout the country and hot in the south. The country experiences occasional floods and droughts. Sea levels appear to be currently rising at about 2-3 mm annually.

Terrain: Ukraine is mostly fertile steppes (or plains) with the Carpathian Mountains in the west and mountains on the extreme south of Crimea. Figure 2 is a shaded relief map of Ukraine. Note its highlands, lowlands, marshes, and drainages which have military consequences.

Figure 2: Shaded relief map of Ukraine (DataIs Beautiful, 2022)

Figure 3 shows the soils of Ukraine.

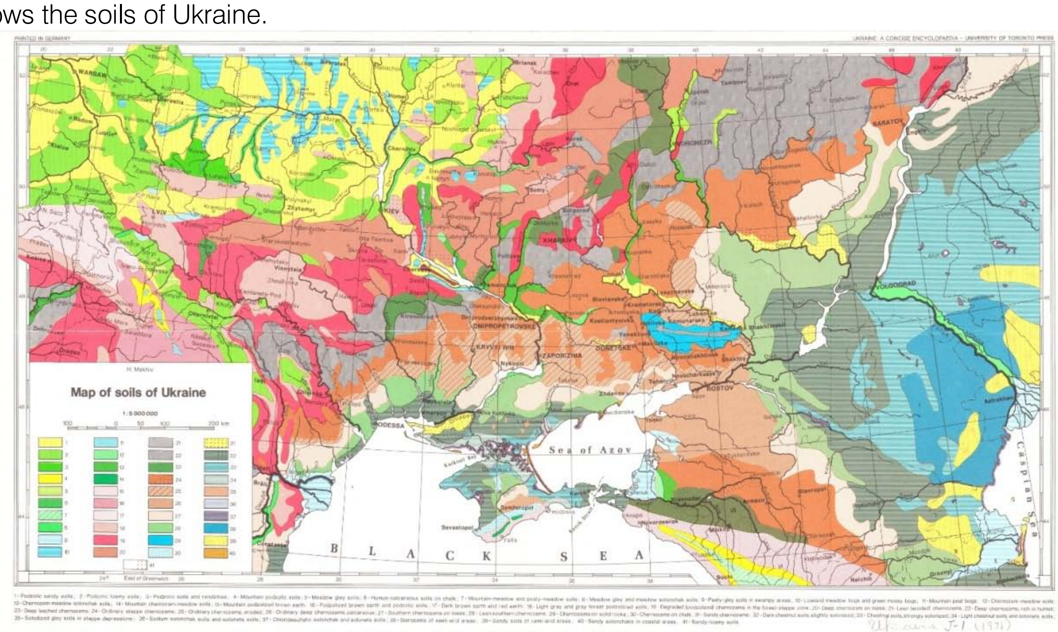

Figure 3: Soil map of Ukraine (Archive, 1971)

Figure 4 shows a geologic structure map of Ukraine. According to GeoMap (no date), the most common in the geological structure of Ukraine is Precambrian, Paleozoic (especially coal-period), Mesozoic (Including the Cretaceous period), and particularly Cenozoic sediments. Among anthropogenic deposits are glacial sediments, water-glacial, aeolian, and alluvial materials.

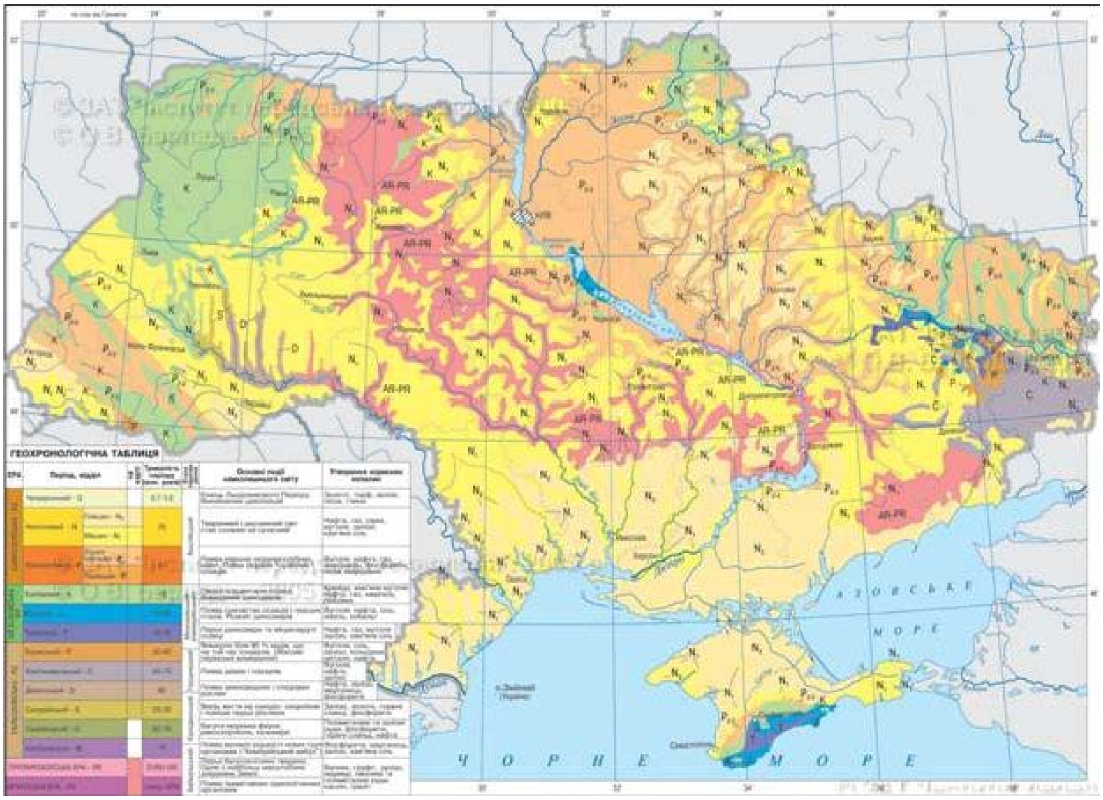

Figure 4: Geologic structure of Ukraine (no date)

Natural Resources: Ukraine's natural resources include abundant fresh water, navigable rivers, river ports, iron and manganese ores, anthracite and bituminous coal, lignite (brown coal), natural gas, oil, uranium, salt, sulfur, graphite, titanium, magnesium, kaolin, nickel, mercury, rare earth minerals and gold, limestone and aggregates, timber and non-timber forest products (Christmas trees, Pine needle extracts, mushrooms, berries, birch syrup), arable land, maritime routes, and deep natural ports.

Military Geology: Some of the salient military geology aspects of Ukraine include its radioactive soils and potential releases, tunnels, marshes, rivers and dams, and bridges.

Radioactive Soils: Ukraine's radioactive soils and potential radioactive releases from and around its nuclear plants pose a Ukrainian and regional risk, but a potential Russian advantage.

According to the Encyclopedia Britannica (no date), from northwest to southeast, the soils of Ukraine consist of: 1. A zone of sandy podzolized soils; 2. A central belt of black, extremely fertile chernozems; and 3. Chestnut and salinized soils.

Tunnels: Limestone tunnels as much as ten stories deep and over 15 miles long at Odesa in the south, as well as rock tunnels at its capitol Kyiv in the north and industrial Mariupol in the east, provide military and civilian refuge areas. They pose a hazard to the Russians.

The average and maximum depths of the Neogene unconsolidated rock cover are about 25 and 100 meters, respectively, indicating that hard rock is available below these depths for deep tunnels and underground subway train corridors. To refresh, the Neogene Period was a time of big changes in the earth when the climate became cooler and drier, grasslands replaced forests, and animals adapted or became extinct.

The Pinsk Marshes: Per Ledur et al (2022), "To Ukraine's north span roughly 100,000 square miles of wetlands known as the Pinsk Marshes. Here is one place the cold could really play a role. During the winter, these mucky flatlands freeze over, providing a more stable terrain for heavy military vehicles that would otherwise get stuck in the mud." There are similar marshes along the Belarus border in northern Ukraine.

The Dnieper River: The north-south flowing Dnieper River in central Ukraine, with its critical dams, divides Ukraine into east and west. It's difficult to cross and destruction of its dams and hydropower facilities would lead to catastrophic flooding and loss of electricity.

The Bridge over the Kerch Straits: In 2018, Russia completed this 12-km, $4 billion bridge connecting Russia with its conquered Crimea. It's a very vulnerable linkage for a determined force.

Table 1 summarizes selected natural and anthropogenic situations which are favor offensive and defensive military positions. There are many others, many of which are documented in readily available books and articles available through internet searches. Of course, local and instant conditions may vary from the table.

Table 1: Summary of selected favorable offensive and defensive situations

Situation	Favors Offense	Favors Defense
Radioactive soil	▲	▼
Rivers	▼	▲
Dams and bridges	▲	▼
Hills, uplands, mountains	▼	▲
Valleys and lowlands	▲	▼
Grottos, catacombs, caves	▼	▲
Islands, coasts, open seas, marshes	▲	▼
Forests, tunnels, trenches	▼	▲
Open pastures and fields	▲	▼
Missile and done defenses	▼	▲
Bomb shelters, hospitals, rest and recovery centers	▼	▲
Early warning and alarm systems	▼	▲
Evacuation and resettlement plans	▼	▲

Final Thoughts: A professional miliary forces as well as ad hoc resisters, militias, insurgents are wise to utilize the advantages of geologic factors. Yet there is much more than that to winning and losing battles and wars. Forces who command higher communication information and intelligence technology, morals, flexibility, staying power, surprise elements, veteran troops, initiative, troop rotations, field health, advanced scouting and technology, and other factors are more likely to succeed in their objectives.

Author and Acknowledgements

Mr. Popkin is a geologist, soil scientist, hydrologist, environmental engineer, and water and waste manager. He has over 50 years of experience in more than 30 U.S. states and as many countries, including Bashkiria, Georgia, Kosovo, and Tajikistan. His grandparents immigrated to the U.S. from Eastern Europe over 100 years ago. Mr. Popkin is grateful to Dr. Chisholm at NYU, Mr. Summers at NMT, and Dr. Holmes at Missouri S&T for sharing their insights to military geology.

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Chemical, Mineralogical and Physical Characteristics of a Material Accumulated on the River Margin from Mud Flowing from the Collapse of the Iron Ore Tailings Dam in Bento Rodrigues, Minas Gerais, Brazil

By Alexandre Christofaro Silva, Luis Carlos Duarte Cavalcante, José Domingos Fabris, Roberto Franco Júnior, Uidemar, Morais Barral, Múcio Mágno de Melo Farnezi, Abraão José Silva Viana, José Domingos Ardisson, Luis Eugenio Fernandez-Outon, Luciano Roni Silva Lara, Humberto Osório Stumpf, João Batista Santos Barbosa & Luiz Carlos da Silva
UFLA

Abstract- The rupture of an itabirito mining tailings dam at the headwaters of the Doce River Basin (Minas Gerais and Espírito Santo, Brazil) caused the greatest environmental catastrophe of the planet Earth related to this activity. The tailings were deposited both in the bottom and on the riverside terrace of the rivers, causing silting and deep changes in the water quality and burial of the main agricultural areas of this basin. For these areas to return to pre-disaster levels, it is imperative that the material deposited on the river terraces be thoroughly characterized. The objective of this work was to characterize the material from the rupture of the Fundão dam, deposited on the river terrace of the Carmo River, a tributary of the Doce River. The material was collected at a depth of 0 to 30 cm from a tail layer about 3 meters thick deposited on the river terrace on the right bank of the Carmo River in the urban area of Barra Longa, Minas Gerais.

Keywords: *heavy metals, contamination, recovery of degraded areas, agricultural areas.*

GJHSS-B Classification: *FOR Code: 091405*

CHEMICALMINERALOGICALANDPHYSICALCHARACTERISTICSOFAMATERIALACCUMULATEDONTHERIVERMARGINFROMMUDFLOWINGFROMTHECOLLAPSEOFTHEIRONORETAILINGSDAMINBENTORODRIG
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Strictly as per the compliance and regulations of:

Chemical, Mineralogical and Physical Characteristics of a Material Accumulated on the River Margin from Mud Flowing from the Collapse of the Iron Ore Tailings Dam in Bento Rodrigues, Minas Gerais, Brazil

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Abstract- The rupture of an itabirito mining tailings dam at the headwaters of the Doce River Basin (Minas Gerais and Espírito Santo,Brazil) caused the greatest environmental catastrophe of the planet Earth related to this activity. The tailings were deposited both in thebottom and on the riverside terrace of the rivers, causing silting and deep changes in the water quality and burial of the main agriculturalareas of this basin. For these areas to return to pre-disaster levels, it is imperative that the material deposited on the river terraces be thoroughly characterized. The objective of this work was to characterize the material from the rupture of the Fundão dam, deposited on the river terrace of the Carmo River, a tributary of the Doce River. The material was collected at a depth of 0 to 30 cm from a tail layer about 3 meters thick deposited on the river terrace on the right bank of the Carmo River in the urban area of Barra Longa, Minas Gerais. The physical analyses included soil, particle and porosity density, chemical analyses were pH, sorption complex, organic matter, exchangeable Fe, Mn, Cu, Zn, Pb, Cd and Ni, total oxides, and mineralogical analyses were performed by X-ray diffractometer and Mössbauer spectrometry. The reject has high levels of sand and silt and a low clay content. The densities of soil and particles are high, and the porosity is low. The pH is alkaline, the levels of organic matter, plant nutrients and CEC are very low. The exchangeable heavy metals Zn, Cd, Cu, Pb and Ni are very low, and the exchangeable Mn contents of the tailings are high. The predominant total oxides ofthe tailings are SiO_2 and Fe_2O_3. The most abundant minerals of the tailings are quartz and hematite. The physical, chemical, and mineralogical attributes of mine tailings restrict the restoration of native vegetation or the agricultural use of the river terraces on which it was deposited.

Keywords: heavy metals, contamination, recovery of degraded areas, agricultural areas.

I. Introduction

The rupture, on 5 November, 2015, of the dam containing an aqueous suspension of mining tailings from iron ores of an itabirite rock (a metamorphic rock used for the exploitation of iron ore) deposit caused the largest documented environmental catastrophe of the planet Earth related to this activity. The disruption of the Fundão dam, located at the headwaters of theGualaxo do Norte River, a tributary of the upper reaches of the Doce River, released more than 60 million m^3 of sandy andclayey rejects as muds. By moving downstream, the muddestroyed two districts of the municipality of Mariana, state of Minas Gerais, namely Bento Rodrigues and Paracatu de Baixo, impacted thousands of hectares of agricultural areas, and hasleft several cities in the states of Minas Gerais and Espírito Santo virtually desvated ever since. The rejects carried by thewater flux reached the mouth of the Doce River anddramatically affected the fauna and flora, as in mangroves, ofits ecosystem. More than one million people were affected andnineteen persons died. The overall losses were estimated as being about five billion dollars (Milanez and Losekann 2016).

The mineral rejects were deposited both in the bottom and on the riverside terrace of the Gualaxo do Norte, Carmo and Doce rivers, causing siltation and profound changes in the water quality and covered the main agricultural areas of the valleys, in irreversible environmental impacts. In the first 90 km, following the Gualaxo do Norte and Carmo Riverflows, and along with a small part of the Doce River, the tailing streams descended rapidly, and materials of varying chemical composition and granulometry were deposited both on the bottom and on the river banks. A flood was generated by mudflows and severely affected the fluvial

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plain with deposits of various thicknesses (Milanez and Losekann 2016), as in the municipality of Barra Longa, destroying much of its agriculture-based economy. Upon reaching the dam of the Risoleta Neves Hydroelectric Plant, the coarser material was barred; only materials of predominantly finer granulometry were and are transported downstream from that point.

Agriculture and livestock are two of the main economic activities of populations in the Doce River valley. The riverine areas are the most suitable and have been the most intensely used for farming and pasture. Any effort to gradually return to pre-disaster quality levels necessarily imply a better knowledge and require thorough investigations regarding the mineralogical nature of the deposited materials on the river terraces.

II. Materials and Methods

a) Sample collection point description

The material from the rupture of the Fundão dam was collected on November 20, 2015, at a depth between 0 to 30 cm from the surface of a mud mantle about 3 m thick deposited on the right margin terrace of the Carmo River, in the urban area of the municipality of Barra Longa, in the state of Minas Gerais. The sampling site is located at 385 m above sea level, at UTM coordinates (23K) 704623 South and 7756199 West, in an anthropic area previously used for the raising of domestic animals and fruit trees. The geographical location of the sampling point, along with those of the dams of mining tailings, the city of Barra Longa and the county of Bento Rodrigues, before and after the rupture of the Fundão dam are shown in Figure 1.

b) Physical Analyses

All granulometric analyses (to assess the proportions of sand, silt and clay) were made in the triplicate: clay was determined by the pipette method, whereas the sand content was obtained by sieving. The soil density (Ds) was determined by the volumetric ring method, where as the particle density (Dp) was assessed by the volumetric flask method, according to the method described by Embrapa (2011). The total pore volume (VTP) was calculated by Erro! Fonte de referêncianão encontrada.

$$VTP = 1 - \left(\frac{D_s}{D_p}\right) x\ 100$$

Erro! Fonte de referência não encontrada.

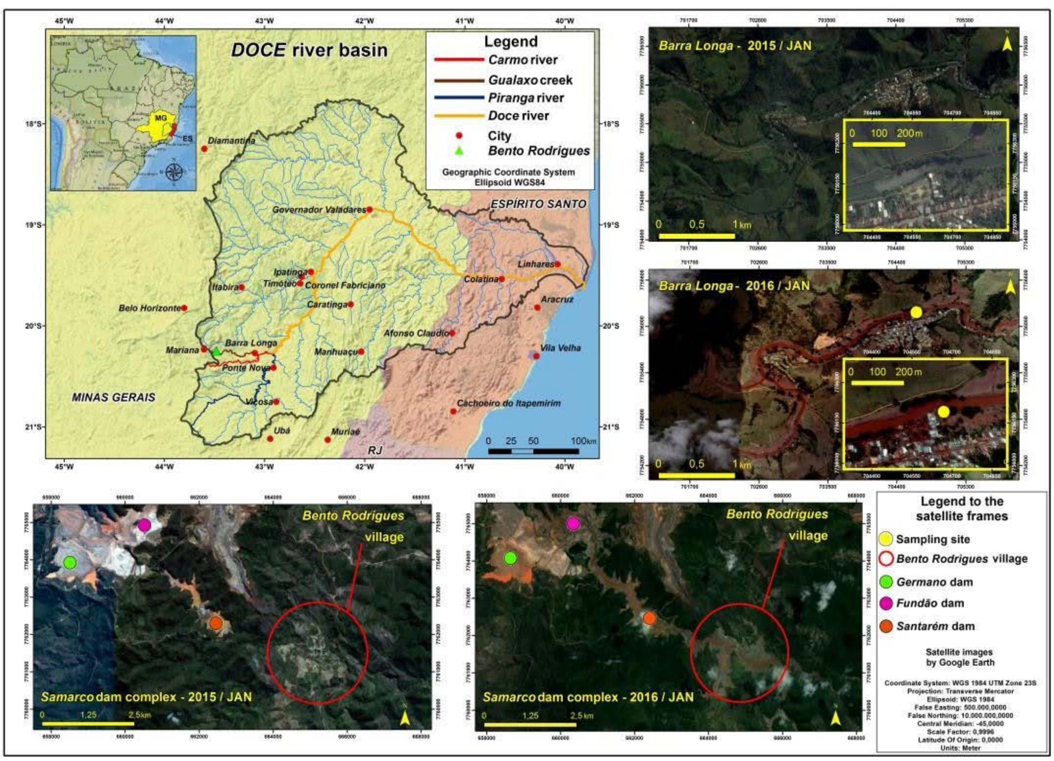

Figure 1: Upper left: the geographical context of the Doce River basin. The two pictures at the right show the sampling site in Barra Longa (just before the dam rupture, in 2015, and several months after, in 2016). The bottom pictures show the Samarco dam complex and the Bento Rodrigues county (also, in 2015and in 2016).

c) Chemical Analyses

Routine chemical analyses for soils and sediments (pH in water, organic matter, available P, Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, Al^{3+}, H + Al) and for the Fe, Zn, Mn, Cd, Pb and Ni contents were performed in triplicate, according to methods described in Embrapa (2011). The sum of bases (SB), the effective cation exchange capacity (t), the cation exchange capacity at pH 7 (T), the saturation by base (V) and the saturation by aluminum (m) were obtained.

The determination of the C, H and N contents in the sample was performed in triplicate, with a LECO TruSpec Micro elemental analyzer equipped with an infrared detector. The samples were burned at 1075 °C in a quartz tube to quantify theC, H, and N contents.

The X-ray fluorescence analysis of the sample was performed with a Shimadzu EDX-720 energy dispersive X-ray fluorescence spectrometer, with a rhodium tube and silicon- lithium detector. Data were collected under vacuum of 40 Pa with a 10-mm collimator.

d) Mineralogical Analyses

The powder X-ray diffraction (XRD) pattern for the sample was collected in a Rigaku model D/Max Ultima Plus diffractometer set to a current of 30 mA and a voltage of 40 kV, with CuKα ($\lambda = 1.541838$ Å) radiation, at a scan rate of 1° 2θ min^{-1}, from 4° to 100° 2θ. Silicon was used as the external

e) Mössbauer spectroscopy

The Mössbauer spectra were collected at room temperature (~298 K), 80 K and 25 K in a conventional transmission spectrometer at a constant acceleration configuration with a $^{57}Co/Rh$ gamma-ray source and nominal activity of about ~25 mCi. Doppler velocities were approximately ±11.6 mm s^{-1}. Mössbauer isomer shifts are quoted relative to an α-Fe foil at room temperature. The experimental data were fitted with Lorentzian functions by least-square fitting with a NORMOS™- 90 computer program. Magnetization measurements were performed with a vibrating sample magnetometer (Lake Shore7404; with a noise base of 5 x 10^{-5} emu, a time constant of 100 ms at room temperature, and a maximum magnetic field of 2 T).

III. Results and Discussion

The mine reject was found to have a sandy loam size distribution (Embrapa 2013) and low clay content. Shaefer *et al.* (2016) found similar granulometric compositions in samples collected at several points close to the sampling of this study. The bulk density (Ds) of the tailings was relatively high, as was the particle density (Dp). These characteristics explain their very low porosity (Table 1). Shaefer *et al.* (2016) obtained Ds values between 0.94 and 2.38 g cm^{-3} and mean Dp values between 2.75 and 2.80 g cm^{-3}. These reported data corroborate the results of this study. All these attributes make it difficult to re-establish the vegetation covering on the terraces, which are the areas with the best agricultural capacity, being most intensively used for agricultural crops and raising of livestock.

Shaefer *et al.* (2016) also pointed out that the settlement of the tailings progressively led to the hardening of the surface, In addition, the slow reestablishment of the vegetation covering in these terraces tends to favor the transport of the deposited waste by the waterways during the annual flood periods, making it a cyclical event.

Table 1: Grain size composition, soil density (Ds), particle density (Dp) and total pore volume (VTP) for the sample of mine tailings. The number in parentheses represents the uncertainty with respect to the last significant digit, as obtained from standard deviations of the mean, estimated from the measuments in triplicate.

Sand	Silt	Clay	Ds	Dp	VTP
	%		t m^{-3}		%
58(2)	36(2)	6(1)	2.12(1)	2.85(8)	25.6

The mining reject is alkaline and very poor in nutrients, presenting only moderate Ca contents (CFSEMG, 1999). According to *Shaefer et al.* (2016), the high pH value can be due to the use of NaOH in the beneficiation of the ore. The CEC value is very low because of the low clay and organic matter contents (Tables 1 and 2) and the highly oxidized nature of the 2016). Soils and petroplintites from the region of this study (Quadrilátero Ferrífero) also present a low CEC (Sahefer *et al.* 2015). CHN analysis yielded approximately 0.50 mass% of C, 0.06 mass% of N and 0.07 mass% of H, corroborating the small content of organic matter in the sample (Table 2).

Table 2: Chemical attributes and contents of metallic elements of the sample of mine tailings. OM: organic matter; BS: sum of bases; CEC: cation exchange capacity at pH 7; V: saturation by bases; m: aluminum saturation; nd: not detected.

pH (water)	P	K	Ca	Mg	Al	H+Al	BS	CEC	m	V	OM	Na	Fe	Zn	Cu	Mn	Cd	Pb	Ni
1:1	mg dm^{-3}			------------------$cmol_c$ dm^{-3}------------					------%-----		dag kg^{-1}				---------------------------mg dm^{-3}-----------------------------				
8.24	3.58	1.44	1.76	0.02	nd	0.95	1.79	2.74	nd	65.20	0.71	1.67	409.2	1.5	2.4	441.4	nd	1.9	0.9

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The percentages of heavy metals encountered — Cu, Cd, Pb and Ni in the form available for the plant use — are small or not detected, except for Fe and Mn, which are high (Table 2). Shaefer et al. (2016) found mean Fe and Pb levels of 499.2 and 0.41 mg dm^{-3}, respectively, in samples of tailings from the same region, similar to those found in this study (Table 2).

Although Mn and Fe are plant micronutrients, high levels such as those found in the tailings (Table 2) can be toxic to plants (CFSEMG, 1999). The Mn and Fe contents in the waters of the Carmo River and the Doce River, respectively, were greater than the levels allowed for class 2 water (waters that can be destined for human consumption, after conventional treatment to protect aquatic communities and recreation), according to CONAMA Resolution 357 (Milanez and Losekann, 2016). The chemical attributes in the set do not favor the establishment of a vegetal cover.

A predominance of Si and Fe was observed by the X-ray fluorescence analysis (Table 3). Brant Meio Ambiente (2005) found similar Si and Fe values in the material deposited at the Fundão dam, 62.39 and 40.43 mass% (weighted average between clayey tailings and sandy tailings), respectively. Si predominates in both the sand fraction and the silt fraction (Table 1), which are the main wastes from the itabirite mine. The high Fe contents, both in oxide form and in the exchangeable form (Tables 3 and 2), indicate that the ore beneficiation process was not very efficient.

Table 3: Chemical composition of the sample as determined by X-ray fluorescence spectroscopy.The numbers in parentheses are uncertainties with respect to the last significant digit, as provided by the spectrometer.

	Oxides Content/Mass%
SiO_2	53.2(1)
Fe_2O_3	37.33(3)
Al_2O_3	8.45(5)
SO_3	0.47(1)
K_2O	0.250(1)
MnO	0.127(1)
CaO	0.083(1)
P_2O_5	0.07(2)
CuO	0.017(1)
ZnO	0.002(1)
NiO	0.001(2)

Al was not detected in the exchangeable form, but its contents were significant in the oxide form (Tables 2 and 3). Brant Meio Ambiente (2005) also found significant levels of total Al. The Mn concentrations are low in the oxide form (Table 3) and similar to those found by Brant Meio Ambiente (2005), but they are high in the exchangeable form (Table 2). The Cu, Zn, Pb and Ni concentrations are low both in the oxide form and in the exchangeable form (Tables 3 and 2). The levels of these heavy metals in the waters of the Carmo River and the Doce River were lower than the levels allowed for class 2 water, according to resolution CONAMA 357 (Milanez and Losekann 2016).

The results of the mineralogical analysis (Figure 2) are in line with the results from the physical and chemical analyses. Characteristic reflections of the crystallographic phases for quartz SiO_2 (JCPDS card # 46-1045), hematite, αFe_2O_3 (JCPDS card # 33-664), goethite, αFeOOH (JCPDS card # 29-713), muscovite, $KAl_2Si_3AlO_{10}(OH)_2$ (JCPDS card # 7-25) and kaolinite, $Al_2Si_2O_5(OH)_4$ (JCPDS card # 58-2001) were observed in the X-ray diffraction pattern. Schaefer et al. (2016) found quartz, goethite, hematite, and kaolinite in the tailings of the Germano and Santarém dams near the Fundão dam.

Si predominates in the sand and silt fractions, which together correspond to 94 mass% of all the material (Table 1). The kaolinite and Muscovite (Figure 2) correspond to minerals present in the silt and clay fractions. All the minerals identified have low CEC, corroborating the results of the chemical analyses (Table 2).

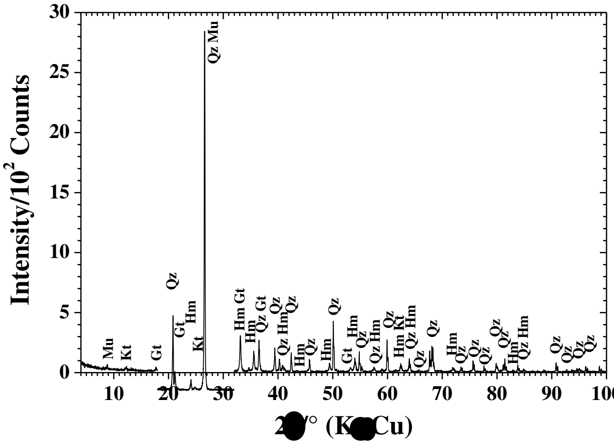

Figure 2: Powder X-ray diffraction pattern of the sample. Qz = quartz, Hm = hematite, Gt = goethite, Mu = muscovite, Kt = kaolinite.

From the Mössbauer measurements (spectra in Figure 3 and corresponding hyperfine data in Table 4), hematite (αFe_2O_3), in greater proportion, and goethite ($\alpha FeOOH$) were identified, corroborating the results of the mineralogical analysis by X-ray diffraction (Figure 2). The predominant portion of this hematite was found to undergo the Morin transition (characteristic temperature, $T_M \sim$ 260 K), with a quadrupole shift from 0.485(2) mm s^{-1} (at 80 K). This fraction is likely to be composed of larger particles of less isomorphically substituted and better crystallized hematite than that not undergoing the Morin transition. In addition to these Fe minerals, a small proportion of maghemite (γFe_2O_3), a magnetic mineral usually associated with hematite and found in highly weathered materials of tropical and subtropical regions, was also identified (Breemen and Buurman, 2002).

Table 4: Mössbauer parameters corresponding to spectrum recorded at 80 K. δ = isomer shift relative to αFe; 2ε = quadrupole shift; Γ = line width; Bhf = magnetic hyperfine field; RA = relative subspectral area. (*) Fixed parameter during the fitting procedure. (**) Constrained parameter during least- squares fitting convergence. The number in parentheses are uncertainties over the last significant digit, as was estimated from the least squares fitting algorithm.

Temperature/K	Fe site	δ/mm s^{-1}	2ε/mm s^{-1}	Γ/mm s^{-1}	*Bhf*/T	*AR*/%
80	αFe_2O_3	0.485(2)	0.385(5)	0.354(9)**	53.75(2)	51(1)
	αFe_2O_3	0.48(1)	-0.18*	0.354(9)**	53.2(1)	9(1)
	γFe_2O_3	0.59(3)	0*	0.354(9)**	48.9(2)	4(3)
	$\alpha FeOOH$	0.435(7)	-0.22(4)	0.49(3)	49.4(5)	36(5)

To minimize this degradation, some measures were experimentally tested by a team from the Federal University of Viçosa (Shaefer *et al.* 2016). The characterization of the material with a view to its use as a substrate for plants, including those to be used in the restoration of riparian forests, or its use as a raw material for civil construction are among the contributions of soil science proposed by Viana and Costa (2016) for the recovery of areas affected by the disaster. This is the main contribution of this work.

Figure 4 shows the magnetization hysteresis curve for the mine tailings sample. The saturation magnetization, Ms, is of 0.66(3) emu g-1; the remnant magnetization, Mr, is of 0.11(3) emu g-1 and the coercivity, Hc, is of 238.38(4) Oe.

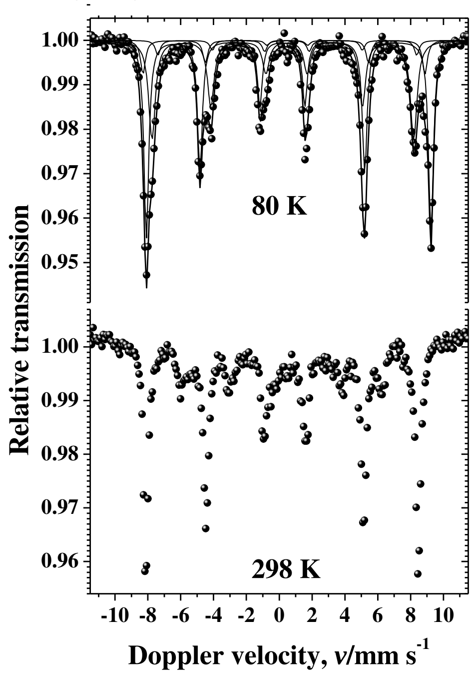

Figure 3: ^{57}Fe Mössbauer spectra for the sample registered at 298 K and 80 K.

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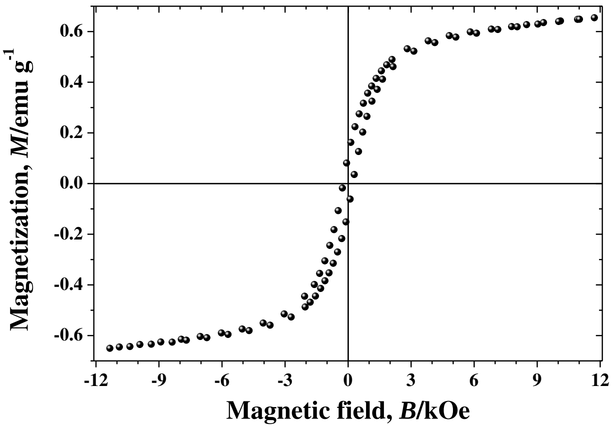

Figure 4: Magnetization curve for the sample at room temperature.

Both the physical, chemical and mineralogical attributes of mine tailings deposited on river terraces of the Gualaxo do Norte River restrict the restoration of native vegetation cover or agricultural activities. The main limiting factors are the high density and low porosity and the high exchangeable Mn contents. The exposed soil favors erosion on these terraces, making it even more difficult to restore vegetation and causing the silting of the river bed and contamination of its waters with Mn. The erosion-assortion-contamination cycle will be repeated annually, especially during rainy periods, to further degrade natural resources.

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IV. Conclusions

- The reject has high levels of sand and silt and a small clay content. Its densities of soil and particles are high, and the porosity is low.
- The pH is alkaline ante the contents of organic matter; plant nutrients and CEC are very low.
- The concentrations of exchangeable heavy metals Zn, Cd, Cu, Pb and Ni are very low and the exchangeable Mn contents of the tailings are large.
- The predominant total oxides of the tailings are SiO2 and Fe2O3.
- The most abundant minerals of the tailings are quartz and hematite.
- The physical, chemical and mineralogical attributes of mine tailings restrict the restoration of native vegetation or the agricultural use of the river terraces on which it was deposited.

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Comprehensive Trend Analysis of Past Century Indian Summer Monsoon Rainfall and its Variability

By Manas Ranjan Mohanty, Sundeep Kumar Baraik & Uma Charan Mohanty

IIT Bhubaneswar

Abstract- The importance of rainfall for an agrarian economy like India is quite well known, especially during the Indian summer monsoon months viz. June through September. Analysis of rainfall characteristics over the past century can present an idea of the variability of rainfall. Variability of rainfall has been observed in intraseasonal as well as intra-annual time scales. This study is aimed at comprehensively analyzing the annual as well as seasonal rainfall trends over India and different homogenous rainfall regions of India over a period of 119 years (1901-2019). Results from the study infer that there has been an increasing trend in rainfall over low rainfall regions such as northeast India there is a decreasing trend over central and northeastern India. The annual rainfall and monsoon rainfall over India as a whole present an increasing trend but the number of extreme rainfall years have increased in recent times. A major concern of decreasing rainfall has been observed over central India where there is a decreasing rainfall trend with an increase in the number of break days over the past 30-40 years. Major findings of this study are that the number of excess/deficit monsoon seasons has rapidly increased post-1960 with more deficit rainfall years.

Keywords: indian summer monsoon rainfall; climate variability; rainfall trends; innovative trend analysis; recurrence interval.

GJHSS-B Classification: *DDC Code: 616.98 LCC Code: RA600*

COMPREHENSIVETRENDANALYSISOFPASTCENTURYINDIANSUMMERMONSOONRAINFALLANDITSVARIABILITY

Strictly as per the compliance and regulations of:

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Manas Ranjan Mohanty [α], Sundeep Kumar Baraik [σ] & Uma Charan Mohanty [ρ]

Abstract- The importance of rainfall for an agrarian economy like India is quite well known, especially during the Indian summer monsoon months viz. June through September. Analysis of rainfall characteristics over the past century can present an idea of the variability of rainfall. Variability of rainfall has been observed in intraseasonal as well as intra-annual time scales. This study is aimed at comprehensively analyzing the annual as well as seasonal rainfall trends over India and different homogenous rainfall regions of India over a period of 119 years (1901-2019). Results from the study infer that there has been an increasing trend in rainfall over low rainfall regions such as northeast India there is a decreasing trend over central and northeastern India. The annual rainfall and monsoon rainfall over India as a whole present an increasing trend but the number of extreme rainfall years have increased in recent times. A major concern of decreasing rainfall has been observed over central India where there is a decreasing rainfall trend with an increase in the number of break days over the past 30-40 years. Major findings of this study are that the number of excess/deficit monsoon seasons has rapidly increased post-1960 with more deficit rainfall years. Whereas, there has been a drastic increase in rainfall in northwest India. The monsoon rainfall variability on multi-decadal time scales also presents that the changing rainfall intensities can play a major role in deciding various factors of the economic activities of India in the context of climate change.

Keywords: indian summer monsoon rainfall; climate variability; rainfall trends; innovative trend analysis; recurrence interval.

I. Introduction

Over the Indian subcontinent and its adjoining Indian Ocean, one of the largest global scale circulations emerges known as the Indian summer monsoon during the months of May-June (*Webster et al., 1998, Mohanty et al., 2019*). Various factors contribute to its genesis, growth and advancement out of which the most important is the land-sea temperature gradient that creates the favourable condition for the seasonal reversal of winds along the equator. Orography over the Indian region is the second factor where the Himalayan Mountains and Tibetan Plateau, that run along the region's northern border and rise steeply from the flatlands of northern India to peak altitudes of 8-10 km above sea level with a mean plateau height of 4-6 km above mean sea level. These highlands not only shield the region from the extremely cold winds of Siberia during the cooler months, but also help to shape the structure of a well-defined southwest monsoon circulation over the region and provide a natural barrier to moisture-laden wind (*Krishnamurthy and Kinter 2003*). The land-sea temperature gradient gives rise to the meridional overturning of the trade winds resulting in the Indian summer monsoon. The heat low crated in the north western India, tropical easterly jet stream, monsoon trough etc. are some of the unique large scale features of the monsoon which control the formation, strength and advancement of the monsoon circulation. Besides these large scale features, complexities are involved in the form of intra-seasonal rainfall variability consisting of active and break phases, mesoscale convective activities, and heterogeneity in spatial rainfall distribution. Combining all the factors the Indian summer monsoon is a very complex atmospheric phenomenon.

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During the summer monsoon season, the Indian subcontinent receives around 80% of its annual rainfall thereby directly influencing the lives of nearly a billion people (*Mooley and Parthasarathy 1984; Kumar et al., 2010*). India as a whole is governed by two prominent monsoon seasons. One is the south west monsoon season or the summer monsoon (June-September) and the other is the north east or winter monsoon season (October-December). During the summer monsoon season, maximum rainfall is observed over the main land region (>80%) whereas during the winter monsoon rainfall is predominantly observed over the peninsular and northern India. Minor discrepancies in rainfall during both the seasons can create severe extreme conditions and hamper the economy of the region. Studying the changing rainfall pattern and its future projections can help in adapting and mitigating the adverse conditions in future. During the summer monsoon season, moisture laden winds in the form of monsoon circulation transport the moisture from the oceans to the land surface in the form of rainfall. Due to this phenomena, agricultural practices as well as hydrological sectors such as mining, industries, hydropower etc. are highly dependent on the rainfall over the June through September months. Though these months are considered as rainy seasons in India, the rainfall during these months is highly variable. The rainfall variability is intra as well as inter seasonal. The rainfall variability within the season and between the seasons adds up to another complexity of the monsoons. Rainfall variability within the season results in active and break phases of the monsoon whereas the rainfall variability between the seasons results in normal, excess or deficit monsoon season. The rainfall variability plays an extremely important role in controlling the economy of the subcontinent. Active and break phases can affect agriculture by excessive flooding or lack of water where as an excess/drought monsoon season can create havocs in the form of hydro-meteorological disasters. Gadgil and Joseph (*2003*) found that prolonged breaks had a negative impact on the country's seasonal monsoon rainfall. During the monsoon season, frequent or extended breaks can result in a rainfall deficit, resulting in a drought-like scenario. Southwest monsoon rainfall and its sustained variability impact the Indian economy adversely because the economic sectors such as agriculture and allied industries, mining, hydropower, etc. are dependent on monsoon rainfall. Minor differences in the summer monsoon strength or delay have had major economic and ecological consequences such as crop loss, droughts, and, in the worst-case starvation (*Kumar et al., 2013*). For example, in Bihar, Assam, and Uttar Pradesh, many lives were lost during the year 1987 where the rainfall was only 29%, 30% and 20% in the July, August and September months (*Singh et al., 2013*). Thus, it's critical to keep a careful eye on rainfall variations around the country on a daily, weekly, monthly, and seasonal basis.

Evidence of rainfall variations have been demonstrated by many observational studies across different regions of the globe (*Dash et al. 2009*). Changes in precipitation at regional scales can result in significant changes in water availability (*Tabari et al., 2020*). One of the major hindrance in studying the rainfall variations over a longer past is the inadequate spatial coverage of the rainfall data sets across different parts of the world (*Hegerl et al 2015, Sarojini et al 2012*). With the availability of large scale observations, quality precipitation data was only available after 1980s. Contemporary climate studies over these 40 years as well as future projection from the Coupled Model Inter-comparison Projects (CMIP) have demonstrated changes in regional as well as global climate and have projected drastic changes in the future climate under different scenarios(*Sharmila et al., 2015*). Anthropogenic activities have been more or less attributed to the climate variations of the past 40 years (*Zhang et al 2007, Marvel and Bonfils 2013*) but they can play a major in deciding the future climate and global scale circulations. Land use and land cover changes along with greenhouse gases emission are the major driver of changes in local scale mean climate which may lead to the changes in large scale circulations and weather systems. Many studies using the climate data of the past 30-40 years have shown that there have been significant changes in climate systems and seasonal cycles of the large-scale circulations. Many studies have shown an increasing trend in rainfall pattern and its intensity over USA and Canada during 1891-1990 (*Groisman and Easterling 1994*). Similar results are also sound over the Mediterranean, Italy and Europe (*Turkes 1996, Caloiero et al 2011, Rio et al 2011, Lukovic et al., 2014*). Over Asia, some studies have found detectable changes in rainfall over different regions. For example, Herath and Ratnayake (*2004*) found a reduction in annual rainfall over central Sri Lanka during the period 1958-2007. Increased pre-monsoon rainfall but decrease in the number of wet days was observed by Sahid (*2011*) over Bangladesh. Increase/decrease in seasonal rainfall have been witnessed over Pakistan/ Malaysia by Salma et al (*2012*)/Mayowa et al (*2015*). Heavy rainfall as well as average rainfall has increased substantially in southern China during the last 3 decades but it has decreased in the middle and lower reaches of Yangtze river (*Duan, A et al. 2013*). Positive trend in the annual and summer rainfall was found over north west parts of Australia which was related increased number of deep convections caused by the monsoon trough (*Taschetto et al. 2009*). Similar studies for determining the past century rainfall trends over Indian main land region and significant rainfall areas of India have been carried out by many researchers. Guhathakurta et al. (*2014*) studied the rainfall pattern over India and observed that the rainfall was decreasing in the monsoon core region post-1950. They also found that multi-decadal variability showed different characteristics over different rainfall homogenous regions of India. Dourte et al. (*2013*) found that the major rainfall characteristics such as the intensity, duration and frequency of rainfall was changing over the past century quite significantly. Similar findings were found by Jin et al. (*2014*), Panda and Kumar (*2014*), Maharana et al., (*2021*) etc. Though the intensity showed an increasing trend, the duration and frequency of rainfall were decreasing which clearly indicated an increase in heavy rainfall events. Regional studies have also been carried out over the southern parts, monsoon core region and north eastern India which showed that rainfall characteristics were changing quite significantly over the past century. Over the southern India, the monsoon rainfall intensity showed an increasing trend (*Raj and Azeez 2010; Saini et al., 2020*). Kuttippurath et al. (*2021*) in his study found that the variation in rainfall at Cherapunji, the planet's wettest place, and illustrated how rainfall patterns have shifted over time and space. The observed shift of the wettest spot from Cherrapunji to Mawsynram has been attributed to the changes in spatial pattern in rainfall in the area over the recent period (1973-2019) in their study.

Focusing on the annual pattern of rainfall, Mini et al. (*2016*), discovered a considerable increase in monthly rainfall during February, March, October, and November, whereas a decrease in the monthly rainfall

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contribution of June and July. They also found a large increase in monthly rainfall during February, March, October, and November, as well as a drop in monthly rainfall contribution during June and July. In January, July, and the Winter season, there was a strong decrease in rainfall whereas in August and September, however, there was an increasing trend (*Saini et al. 2020*) over the Western Ghats. According to Qadimiet al. (*2021*), there is a link between ENSO (El Niño Southern Oscillation) and the Indian Summer Monsoon andhe inferred that deficit rainfall during the monsoon season was linked to El Nino events, with El Nino years responsible for roughly 60% of all droughts in India on the other hand La Nina years were associated with excessive rainfall over India. Because of the south-eastward movement of the walker circulation anomalies, Krishna kumar et al. (*1999*), discovered a weakening link between monsoon rainfall and El Nino. Several regions in India have seen continuous rainfall for more than four days during the summer monsoon season. Throughout the season, the Indian Summer Monsoon is characterized by strong circulation at 850 hPa south-westerlies and 200 hPa upper-level easterly jet. According to Dash et al. (*2004*), a decrease in horizontal and vertical wind shear during the southwest monsoon over India slows the monsoon circulation and reduces rainfall. According to Koteswaram (*1958*), intrusion of weak Tropical Easterly Jet over South India, and upper tropospheric westerlies intruding over North India can cause weak ISM. Southward displacement of the Asian jet is observed to have a substantial impact on ISM rainfall (JJAS) primarily in northern and central India. Weak Tropical Easterly Jet changes the low-level ISM circulation, resulting in less rainfall over India. This continuous rain is due to cyclonic systems which occur in the Bay of Bengal and the Arabian Sea in the form of depressions and deep depressions. A considerable decline in long spells and an increase in short spells over the Indian subcontinent over the recent times indicate that the monsoon system may be weakening *(Dash et al. 2009).* Apart from observational studies, coupled climate modeling studies have indicated changes in rainfall pattern and intensities in the coming future. Anthropogenic emissions and land use land cover changes can have drastic impacts on the future climate and meteorological conditions of a particular region. Further, adverse rainfall scarcities and enhanced extreme weather events may be faced under the RCP 4.5 and 8.5 scenarios in the Indian subcontinent and its adjoining regions (*Salunke et al., 2019; Jain et al., 2019*).
In terms of the trend, having an appropriate statistical significance ensures confidence in the occurrence of a particular event. Analyzing the past trends of rainfall over longer periods can have a very significant impact on the forecasting of rainfall. Combining the past trends and future climatic scenarios can help in the adaptation and mitigation strategies for the upcoming future. The principal motivation for this study comes from the scale of the dependent population on the summer monsoon rainfall over India. With such a large population dependent directly on rainfall over 4 months, it is indeed very important to study the recent trend in monsoon rainfall. Along with it, climate model projections predict a 5 percent to 15 % rise in total summer monsoon rainfall across India, according to the IPCC's fifth assessment report (*Sharmila et al., 2015*). This rise may be credited to the warmer Indian Ocean, which accentuates the land-ocean contrast and so increases the amount of moisture carried to India (*Yadav., 2019*). Along with it, a rise in temperature due to enhanced greenhouse gas emissions may alter the monsoon circulation and in turn, lead to changes in rainfall patterns and intensities.

Many non-parametric tests for trend analysis are available and are employed in hydrological investigations and they found it quite reliable. Because of its high accuracy, repeatability, and flexibility, the non-parametric test is often used in climate change research. Many researchers have used Innovative trend analysis (ITA) in their work, (*Meena et al., 2018*) examined the trend of rainfall in semi-arid regions of western Rajasthan. Caloiero et al.(*2018*) also used Mann-Kendall's Test (MKT) and ITA to analyze the trend of over 500 rain gauge stations in Italy over 50 years. (*Wang et al., 2020*) employed the ITA approach to determine the precipitation trend in eastern China, and the results were consistent with traditional methods. According to the literature survey, there has been limited research on the long-term rainfall pattern over India and the homogeneous region using a combination of MKT and ITA. The ITA test is used in conjunction with the MKT test to describe the precision of the results obtained.

II. Data and Methodology

a) Data used

The IMD gridded rainfall data (*Pai et al. 2014*) prepared from 6955 rainfall measuring stations over the Indian main land region is used to study the past century trends in summer monsoon rainfall. The spatial resolution of the data is 0.25°×0.25° and the temporal extent is from 1901 to 2019 (119 years). The data is unique of its own kind as highest number of stations were used to prepare this data. The data was developed after making quality control of each rain gauge station.

b) Methodology

To study the long-term trend, accumulated seasonal rainfall for the Post-Monsoon (OND), Pre-Monsoon (MAM), South West monsoon (JJAS), and Annual rainfall each year is statistically analyzed in this study. According to various research, India as a whole does not display a particular pattern for ISMR. As a result, the study region is divided into four rainfall homogenous regions (Figure 1) as per the classification

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of IMD: South India, North East India,Central India, and northwest India (*Rajeevan et al., 2010*).

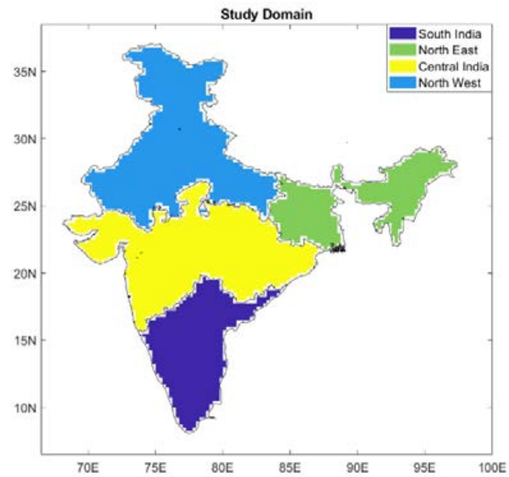

Figure 1: The four rainfall homogeneous regions of India used in this study.

Four distinct rainfall trend analysis methods used in this study are:

- The Mann Kendall test is used to extract seasons that demonstrate a significant trend with a confidence level of 90%.
- The discovered trend is corroborated by the results of a recently established analysis called Innovative trend analysis (ITA) (*Saini et al., 2020*).
- The Weibull's Recurrence Interval (*Saini et al., 2020*).
- Sen's Slope.

i. *Mann Kendall's test*

The Mann-Kendall Test is used to determine whether a time series exhibits a monotonic rising or decreasing trend. The data does not need to be regularly linear or distributed. It does necessitate the absence of autocorrelation (*Mann, 1945*). The null hypothesis in this study is that there is no trend, while the alternative hypothesis is that there is an upward (or downward) trend in the one-sided test or a trend in the two-sided test. Statistical test (m) is defined as follows:

$$m = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} sign\,(x_j - x_i) \qquad ------(i)$$

It's worth noting that if m > 0, earlier observations in the time series tend to be lesser than those appearing later in the time series, and if m = 0, the opposite is true. N denotes the duration of the data series, xj and xi denote the sequential data in the series, and

m's variance (v) is calculated as follows:

$$v = \frac{1}{18}[n(n-1)(2n+5)] \qquad ----- (ii)$$

The following test statistic is used in the MK Test:

$$z = \begin{cases} (m-1)/sq & m > 0 \\ 0 & m = 0 \\ (m+1)/sq & m < 0 \end{cases} \qquad ------(iii)$$

Where sq denotes the square root of the variable. If there is no monotonic trend (the null hypothesis), then z has a conventional normal distribution for time series with more than 10 elements.

P value is calculated by using z score table. Lower p-values indicate that the null hypothesis is rejected, while larger p-values indicate that the null hypothesis is accepted.

In this study, significance levels $\alpha = 0.05$ was used. If the p-value of a test is less than alpha, the test rejects the null hypothesis. If the p-value is greater than alpha, there is insufficient evidence to reject the null hypothesis.

ii. *Innovative Trend Analysis (ITA)*

The ITA approach is commonly used to find trends in hydro-meteorological investigations. Sen (*1968*) invented and suggested it as it eliminates several restrictions, such as those caused by the independent structure of time series, data length, and the presence of normality in the distribution. The steps in this procedure are as follows:

a) The entire data set is split into two halves. In the event of odd data series, the initial observation is not considered.
b) Two parts of the data are arranged in ascending order on the table.
c) A scatter plot is created using the 1st half on the x-axis and the 2nd half on the y-axis.
d) Then a diagonal line is drawn that divides the plot into two halves.
e) The declining and rising trends can be visually observed by locating the scatter plot's point. The

increasing (decreasing) trend in the time series is indicated by the point sitting above (below) the straight line of 45.

iii. *Sen's Slope*

Sen's slope estimate methodology (*Sen, 1968*) is a common non-parametric way of guessing the slope of a regression line that uses the least square method to fit a pair of components in the vector (m, n). The slope's magnitude can be computed using:

$$\text{Sen's Slope} = \text{Median}\left\{\frac{m_j - n_i}{j-i} : i < j\right\}$$

Where j refers to the later year in the dataset in the vector ij, while i correspond to the earlier year. The final slope representing the magnitude of the entire vector of data is the median of all the Sen's slope values for different years.

iv. *Weibull Recurrence Interval or Return Time (T)*

There are several ways of approximating the probabilities of return time, however, we have used Weibull's method to get the recurrence interval in this case. The recurrence period is calculated using the following formula:

a) Ranking the rainfall event based on the amount of seasonal rainfall, ranking highest to lowest (lowest to highest).
b) Calculation of cumulative probability. In this case, n represents the total number of observations, which in this case is 119.

$$C_p = \frac{Rank\ from\ step\ 1}{n}$$

c) Rank Cp from highest to lowest value, resulting in m which is the exceedance/decadence probability rank, and then go to step 4 to calculate the exceedance/decadence probability.
d) Probability of exceedance/decadence calculation (p) is done by,

$$p = \frac{m}{n+1}$$

e) The exceedance/decadence probability (p) is used to calculate the recurrence interval (T). T is the mean interval of occurrence of a rainfall event of greater than or equal to a specific magnitude.

$$T = \frac{1}{p} = \frac{n+1}{m}$$

v. *Active and Break criteria for identifying the intra-seasonal rainfall variability*

To determine the active and break phases, we considered two criteria. Because active and break spells of rainfall are one of the monsoon's most distinctive characteristics, we feel a useful index should be derived from it for this study. We recognize that rainfall in India is heterogeneous, which may influence our index, so we concentrate on a rainfall-based index for central India. To build our index, we applied (*Rajeevan et al. 2006, 2007*) as one of the methods for identifying the active and break spells from the IMD gridded dataset.

First method is computed based on the daily rainfall and its climatological time series on a daily basis were calculated by computing area-averaged rainfall over central India during monsoon over the period of 1901-2019 at each grid point. The standardized rainfall anomaly is chosen when the standardized rainfall anomaly was above (below) +1 (-1) for at least three consecutive days.

Active (break) days were calculated for each day. Then the inter-annual standard deviation of rainfall is divided by the daily rainfall time series after subtracting the climatology. Figure 2 shows an illustration of the methodology followed for identifying the active and break phases during the monsoon season of 1987. Similar methodology is followed for all the monsoon seasons.

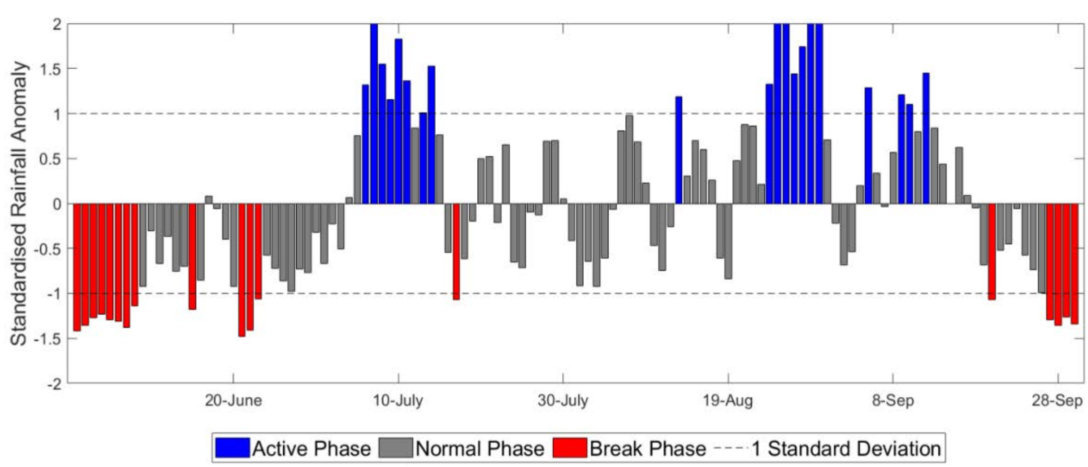

Figure 2: Normalized rainfall anomaly over India for the monsoon season of 1987. The blue and red colour bars show the active and break days, respectively.

Second method is followed by the specifications of IMD for classifying the active and breaks phases where, rainfall should be $1\frac{1}{2}$ times normal to be considered an active phase. Over the region of study, it should rain continuously for at least four days. Rainfall should be less than $\frac{1}{2}$ of usual to be considered a break phase and there should not be any rain beyond the prescribed value continuously for at least four days. The active and break periods are defined as days when the amount of rainfall is more (less) than $1\frac{1}{2}(\frac{1}{2})$ respectively, and this condition should last for at least four days over the region of study.

III. Results and Discussions

This section describes the important findings from the trend analysis of the past century rainfall. Preliminary analysis is carried out using Mann-Kendall's test and Sen's slope estimator. Only those trends found significant are analyzed further using other methods. The results have been divided into two sections where the first section analyzes the rainfall trends during different seasons whereas the second section focuses on the summer monsoon season specifically.

a) Annual and seasonal analysis

Evolution of seasonal and annual rainfall can display a brief idea on the trend in rainfall. Figure 2 shows the time series of the annual and seasonal rainfall over Indian main land region and figure 3 for the four homogenous regions considered in this study. The time series of accumulated precipitation over all India shows an increasing trend in both annual and monsoon rainfall, with slopes of 0.27 and 0.56 respectively. Also, it can be seen that most of contribution to annual rainfall comes from the summer monsoon season. The pre and post monsoon seasons show very less amount of rainfall which typically ranges between 100-200mm per season. The summer monsoon rainfall ranges between 600-800mm with some seasons receiving as high as 950mm rainfall. Similarly, some seasons receive less than 600mm rainfall. This implies the large spread of the monsoon rainfall as well as its variability. The annual rainfall closely flows the pattern of the monsoon rainfall for which the rainfall during the June-September is considered so important for the Indian sub-continent. The annual rainfall ranges between 1000-1200mm which is an accumulation of all the seasons. Considering the rainfall over the past century, the trend line shows an upward slope which suggests the net rainfall has been increasing.

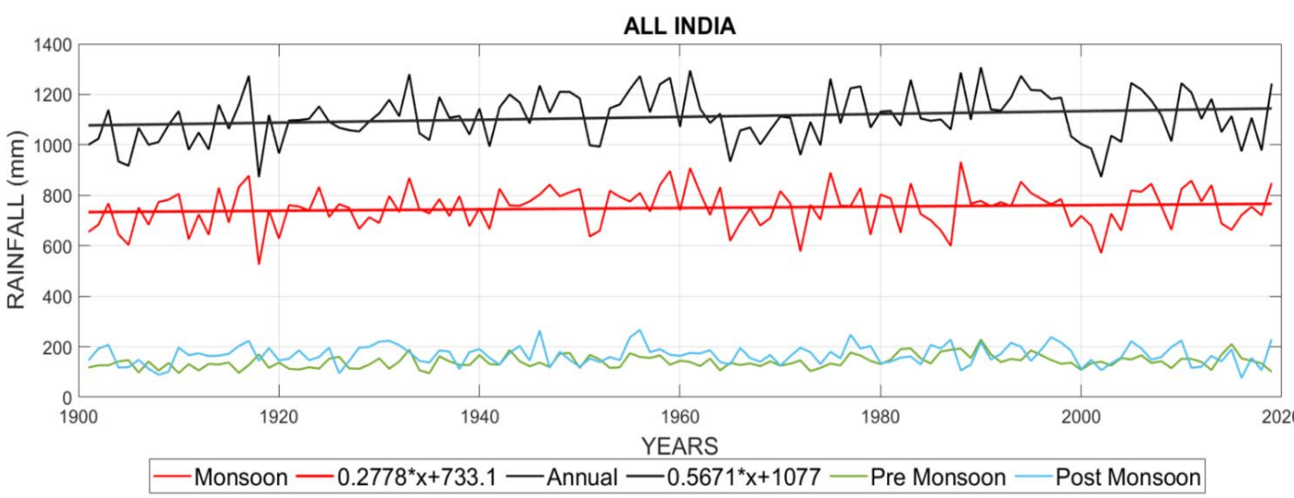

Figure 3: Rainfall trends and time series over the Indian main land region for the summer monsoon (Red line), pre-monsoon (Green line), post-monsoon (Blue line) seasons and annual rainfall (Black line) for the study period of 1901-2019.

Figure 4 shows the similar trend lines as that of Figure 3 but for the four rainfall homogenous regions. Southern India shows distinct pattern from the rest of the three regions where the monsoon rainfall and post-monsoon rainfall have significant contribution to the annual rainfall. The north east or winter monsoon brings significant rainfall over the peninsular India which can be clearly seen from the purple line. The north east India, central and north west India has similar properties to that of the all India rainfall. Most of the contribution of annual rainfall in these three regions comes from the summer monsoon rainfall. On analyzing the rainfall trends, the rainfall shows a strong increasing trend over the arid and dry regions of north west India where as there is a decreasing slope over the heavy rainfall regions of north east India. Over the southern and central India, the trend line is flatter as compared to the other two regions. The slope for the increase is highest in north-western India, at 1.20. Other regions in India have slopes of 0.07 and 0.60, respectively, in the southwest and central regions. A negative slope of 0.14 is seen over the northeast. The trend over Central India and southwest India is almost flat.

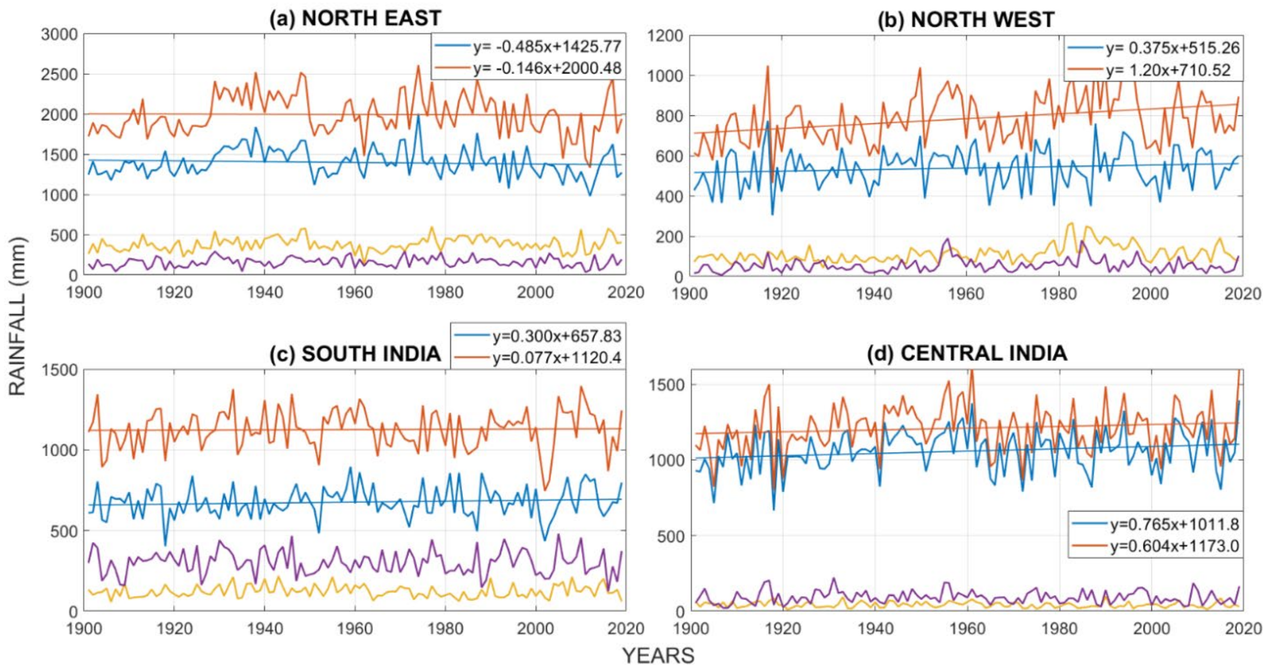

Figure 4: Similar rainfall trends and time series as Figure 3 but for the homogenous rainfall regions of north east, north west, south and central India.

Significant increasing/decreasing trends can be identified using the MKT metric. This method gives the monotonic trend results but corrects the variance. It is widely used to identify the presence of monotonic trends of a parameter. Lower p-values and higher z-values can indicate the strength of trend. Figure 5 shows the p and z values over the regions for the annual and seasonal rainfall considered in this study over India during annual and pre-monsoon, over central India during monsoon, and over the northwest part of India during annual, post-monsoon, and pre-monsoon at a 90% significance level. The annual rainfall across India and the north-western region of India displays an increasing tendency which is significant at 90%. The MMKT data for annual rainfall in Figure 5 reveals a positive z value for India as a whole and the north-western region of India (Dark blue boxes). The z-values are highest over the north east India with 4.32/3.73 for pre-monsoon/annual rainfall. Higher z-values are also observed for pre-monsoon/annual rainfall over India which lies at 3.56/2.25 respectively. Maximum changes in rainfall trends can be seen over the north west India as compared to other regions. The north west India is a dry and arid region and small changes in rainfall or some extreme rainfall events can create a major change in the seasonal and annual rainfall over this region. The annual rainfall over India and the pre-monsoon rainfall over India also show significant changes. Adding to the p-values, z-values from the MKT also show similar results where the changes are witnessed maximum for the North West region and all India as a whole during the pre-monsoon seasons. Minimum p-values are observed over India during pre-monsoon and annual rainfall, over northwest India for all the seasons.

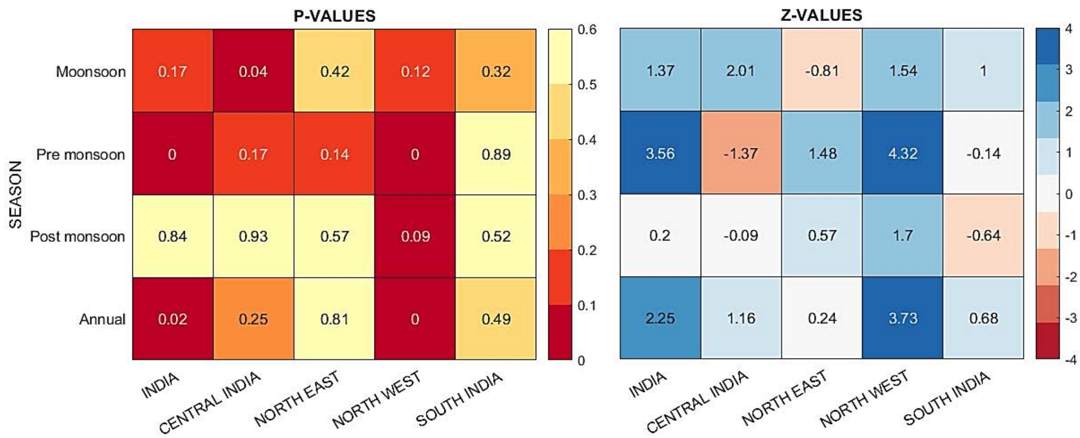

Figure 5: Obtained P and Z values from the Mann-Kendall's test for all India as well the rainfall homogenous regions of India. The values are shown at a significance level of 90%.

From the significant results from the trend analysis and MKT, the ITA approach is studied for the annual, monsoon and pre-monsoon rainfall over India and North West India. The ITA approach can give a brief idea whether the changes in rainfall trends happened in the recent epoch or the farther epoch. The ITA divides the entire time series into two slices thereby giving an idea on the time of change. For the annual and pre monsoon rainfall over India most of the points lie above the diagonal and much closer to the +10% line. This suggests that the rainfall has been increasing quite significantly in the recent 50 years. Some of the points also lie at very high magnitudes which suggest that there has been an increase in the heavy rainfall events recently during the pre-monsoon season. For the monsoon season, the rainfall is quite evenly distributed along the diagonal. Drier seasons were dominant in the earlier tie whereas wetter events are dominant in the recent time for the monsoon rainfall over India. The North West India is witnessing increased rainfall during the pre-monsoon as well as the annual rainfall. The magnitude of the rise in rainfall can be quantified by the Sen's lope and the values for the whole of India is between 0.5 and 1mm year-1, and 1 to 1.5 mm year-1, for the north-western region (Table 1).The trend in central and southwest India is also increasing with magnitudes of 0.36 and 0.16 mm year-1, respectively, however the trend's significance level is less than 90% as obtained from the MKT.

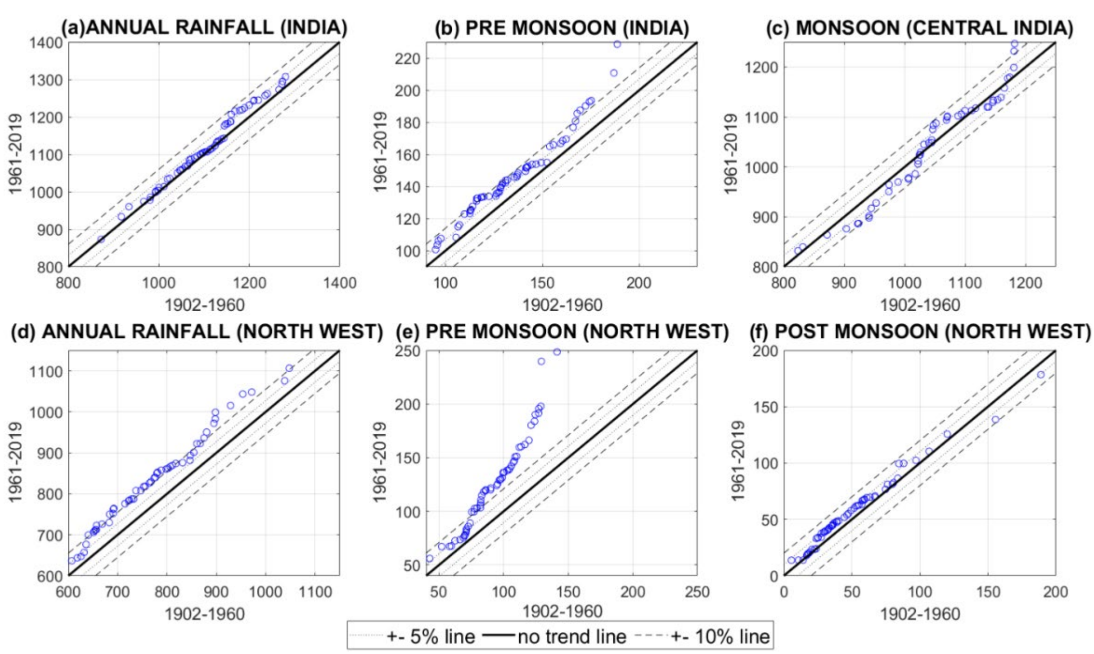

Figure 6: Innovative Trend Analysis (ITA) for (a) annual, (b) pre-monsoon, (c) monsoon, rainfall over India and(d) pre-monsoon (e) post-monsoon and (f) annual rainfall over north west India. X and Y-axis of the figure represent the rainfall (in mm) for the first and second half of the study period 1901–2019. The first half is selected as 1901–1959 and the second half is selected from 1960-2019. The regions are selected based on the Mann-Kendall's test where there is a significant increase/ decrease in trend.

The monsoon season in India is critical for the country's agrarian economy. Figure 3 depicts a decreasing slope in northeast India, whereas the rest of the country has a positive slope. With a slope of 0.76, the highest increasing slope is over Central India. The slopes of the other two regions, southwest and northwest, are 0.30 and 0.37 mm year-1, respectively. A negative slope of -0.48 mm year-1 exists in North East India. Monsoon rainfall over central India exhibit a trend with a significance level of over 90% ($p<0.1$) and a positive z value indicating an increasing trend, according to MKTT results (Figure 5). The ITA also backs up the MKTT result, which shows maximum points on the upward side of the diagonal line which clearly shows a clear rise in trend in the recent epoch. The increasing trend over central India has a magnitude of 0.70 mm year-1according to Sen's slope (Table 1). All India, northwest and southwest region exhibit an increase in the trend with magnitudes of 0.23, 0.36, and 0.19 mm year-1, respectively. The north east region of India shows a falling trend with a magnitude of -0.35mm year-1, but according to the p values the significance level is not 90%.

Table 1: The Sen's slope showing magnitude. Slope significant at 90% level are in bold.

Sen's Slope (mm/year)					
Seasons	India	Central India	North East	North West	South India
Monsoon	0.23	**0.70**	-0.35	0.36	0.19
Pre Monsoon	**0.23**	-0.06	0.30	**0.42**	0.00
Post Monsoon	0.00	-0.02	0.06	**0.10**	-0.13
Annual	**0.54**	0.36	0.01	**1.18**	0.16

The MKT for the pre-monsoon period shows a clear pattern over India as well as in the northwest part of India at a significance level of more than 90% (Fige 3.1). Corresponding z values show a positive trend across India, including the northwest. The ITA (Figure 6 (b), (e)) supports the MKTT result since the maximum points in both scatter plots are on the upward side of the diagonal suggesting a rise in trend in the recent epoch. The trend in India and north-western India is growing at 0.23 and 0.42 mm year-1, respectively. The Sen's slope also reveals a decline in the magnitude of pre-monsoon rainfall in India's northeast, although this was found with a 70% significance level.

During the post-monsoon (OND) season, a significant trend was observed in the north western part of India, with a significance level of 90% (Figure 5). A positive Z value indicates a positive trend. According to the ITA results (Figure 3.3), the trend in the recent epoch is positive as the scatter points are on the upward side of the diagonal. The magnitude of the slope in Table 3.2 suggests that post-monsoon rainfall in India's northwest area is increasing at a rate of 0.10 mm year-1. It also reveals a decrease in trend over south west is not significant at 90%.

b) Monsoon rainfall analysis

i. *Standardized anomaly index*

For determining the anomaly indices during the peak rainfall seasons i.e. the summer monsoon months, the rainfall over India and the Central India region was chosen for an extensive examination of intra-seasonal summer monsoon rainfall in this study. The central India region is often considered as the monsoon core region since the rainfall over this region influences a large population and the economies associated with it. Furthermore, significant rivers such as the Ganga, Mahanadi, and Narmada flow through these plains, and changes in rainfall patterns would affect the water flowing through these rivers, affecting people who live along their banks, farmers, and tertiary sectors of economy. To understand the long term as well epochal trends in rainfall, the anomaly index time series has been divided into slices of 30 years. Figure 7 depicts the normalized anomaly index in blue. The trend over India increased in the first half of the twentieth century (1901–1960) but then began to fall in the second half (1961–2019), as shown in Figure 7 (a). The century trend of monsoon rainfall over India shows an increasing trend. The time period between 1930-1960 had more number of excess rainfall years, especially to the late 50s which may be a reason for the increasing trends in rainfall during the second epoch. During the recent years, the rainfall variability has increased with more number of extreme years. This can be evident from the increased spikes towards the +2 and -2 anomaly levels between the years 1970-2010. Over central India, the rainfall trend increased for the first 30 years (1901–1930), but then had flat or decreeing trend lines after 1930 (Figure 7 b).

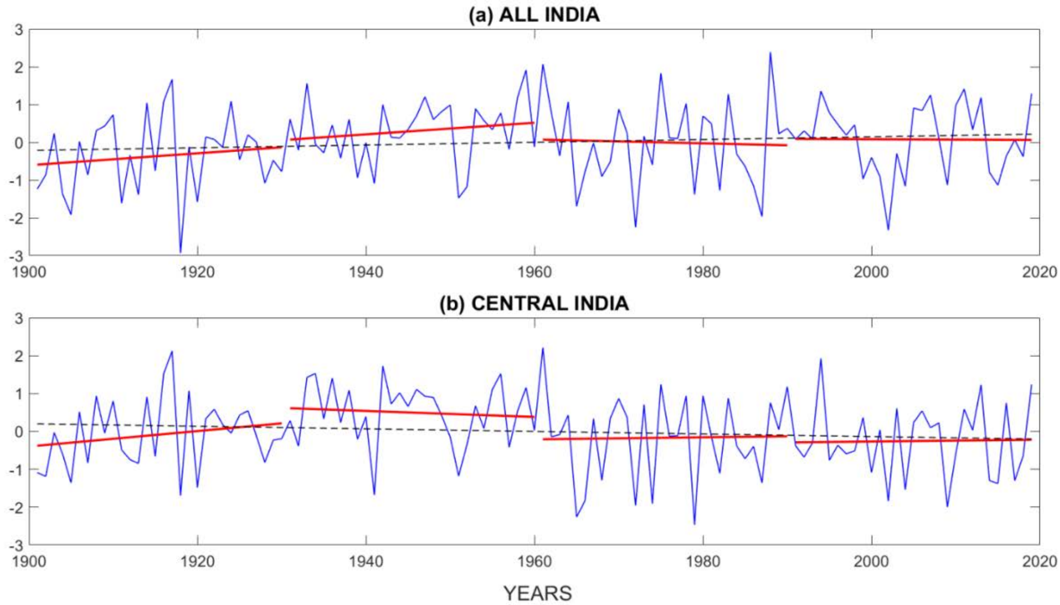

Figure 7: Normalized rainfall anomaly index time series for (a) All India and (b) Central India (blue line) over the 119 monsoon seasons of study. The 119-year rainfall trend is shown in dashed black line whereas the red line is the 30-year trend.

Figure 8 depicts the normal, deficit, and excess years for all India and central India, as well as the 11-year and 30-year running means. Figure 8(a) shows that the number of extreme rainfall years were quite during 1901-1920 which then reduced in number till 1960. Between the years 1920-1960 there were only 6 extreme rainfall events. The extreme rainfall events then took a rise during the recent epoch where there were as many as 16 extreme rainfall monsoon seasons between 1980-2019. Excess rainfall events in India have grown in the second half of the twentieth century (1961-2019) compared to the first half. The height of the bars has also increased, indicating that the intensity of the excess/deficit rainfall has increased. The 30-year moving average lies along the line of zero anomaly which infers that the mean climatological rainfall is quite constant over a 30-year period. But considering the 11-year running mean, there are certain spikes and the number of spikes have increased form 1960 onwards. There have been spikes on both sides of the anomaly index which clearly indicates that there have been more number of extreme rainfall years after 1960. There have been both deficit and excess years in the recent epoch but the intensity of the deficit monsoon seasons are quite robust than the excess monsoon seasons.

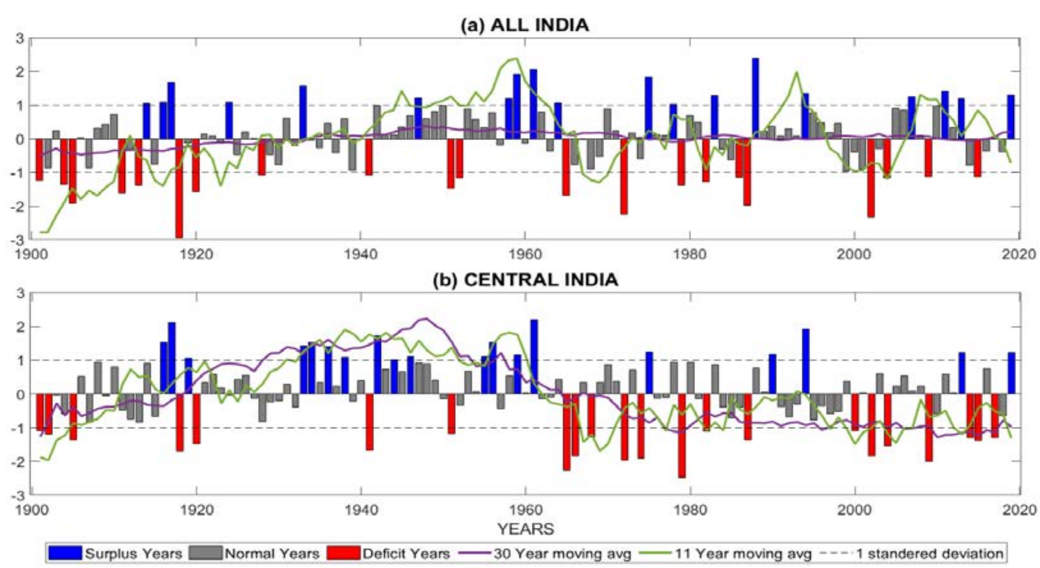

Figure 8: The normalized rainfall anomaly index for (a) All India and (b) Central India with 11-year and 30 year running mean (Green and Purple lines). The blue bar represents the excess year, the red bars represents is deficit years, and grey bars represents normal years.

The normalized anomaly index for central India is shown in Figure 8 (b). In comparison to the top panel, the variability of rainfall over central India is much intense than the all India rainfall. There have been more number of deficit years in the second half whereas there were more number of excess years in the first half. The central India region is thus quite vulnerable as well as quite sensitive to the extreme rainfall during the monsoon season. The 30-year running mean clarifies the variability of rainfall where the mean line was on the positive side in the first half which moved downwards and crossed the centre line during mid-60s, the number of deficit years have increased in the recent times which is a matter of concern since the central India region is quite susceptible to the monsoon rainfall and a large number of population is directly dependent on the rainfall received during the monsoon season. The severity in the increased drought years may be an alarm for the upcoming future for this region.

ii. *Recurrence Interval*

Occurrences of extreme rainfall have been a matter of concern in various parts of the world due to their severe environmental impact. As a result, it has been extensively researched to discover severe events and their probable occurrence in various places. While the current study's trend results indicate the presence of a positive (negative) trend. From 1901 to 2019, we used an SD-based scheme to estimate the occurrence of extreme years, with 1.5 SD (+1.5 SD) denoting excess/flood and -1.5 SD denoting deficit. The excess years are shown by the blue line, while the deficit years are represented by the red line (Figure 9). The recurrence interval (RI) shows the return time of any extreme event with similar intensity. The flood event that occurred over India during the monsoon time in 1961 tends to repeat with similar intensity in nearly 60 years. On average excess as well as deficit event for India's monsoon season is 35 years, which means India can see a deficit of excess rainfall every 35 years approximately. When compared to the first half the data (1901 – 1961), the blue spikes are rising in height for both annual and monsoon precipitation, resulting in a rise in both number and intensity. The increase in the intensity and frequency of drought conditions over India is also indicated by the recurrence interval for deficit years, it is clear that the spikes have increased in the second half (1961-2019).

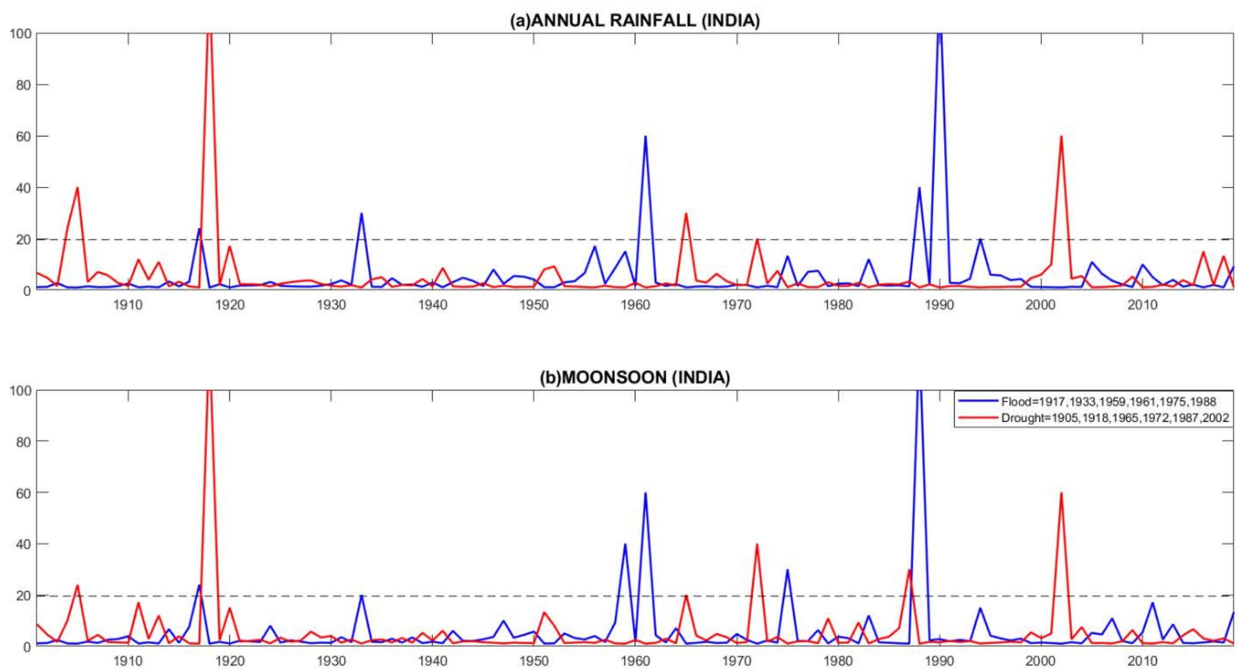

Figure 9: Weibull's recurrence interval period and trends of the excess (+1.5 SD) and (-1.5 SD) rainfall events over the study period for (a) annual and (b) monsoon rainfall. The Blue lines indicate the flood events whereas the red lines depict the intervals of drought events. The dashed lines mark the limit of 1.5SD.

iii. *Intra-seasonal variability*

Figure 10 illustrates the number of active and break days in relation to the average rainfall over India and Central India. Both the methods discussed in section 2.2.5 were used to calculate the total number of active and break days and both the methods showed similar results. The red/black lines represent the total number of active/break days respectively, whereas the grey bars represent the mean seasonal rainfall in mm.day^{-1}. Considering the rainfall over India, the number of active and break days are quite balanced as both the black and red lines lie closely on the chart. Over central India, the number of break days is quite higher than the number of active days for almost all the

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monsoon seasons. As the spikes get higher in the second half after 1960, we can detect a rise in the frequency of the break phase over central India. This increase in the break phase supports figure 10 (b) result, which shows that deficit years are becoming more frequent and intense. The number of active/break days for all India is similar as the low rainfall regions of north west India and high rainfall areas such as the hilly regions of India might be balancing each other when considered as a whole. The increase in the frequency as well as the number of break days over central India may be a concern for the large scale agricultural and other economic activities associated over this particular region.

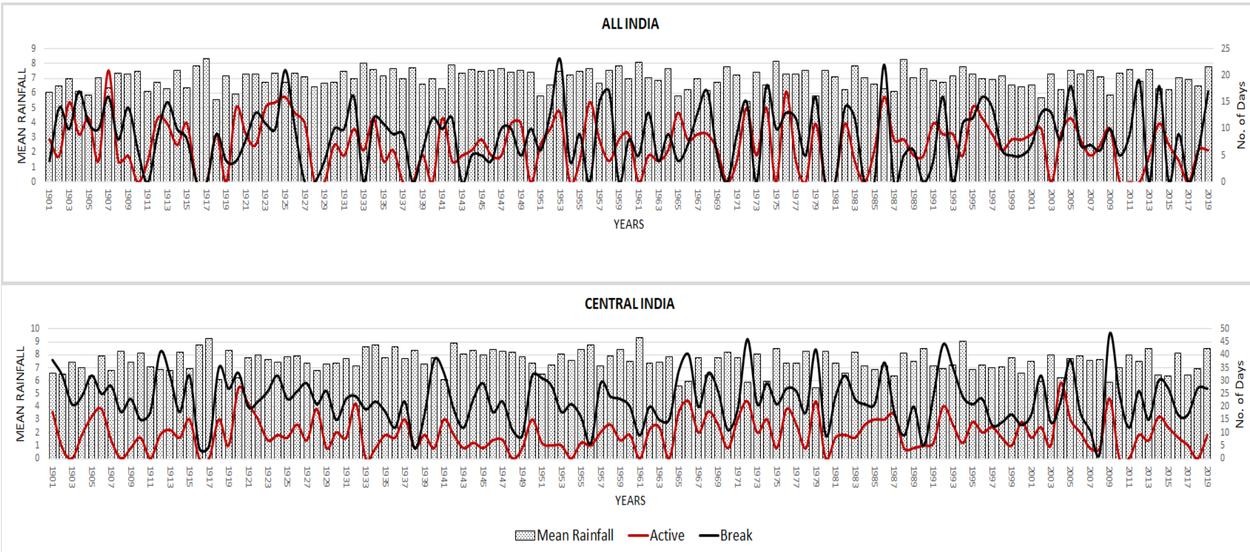

Figure 10: Total number of active (black line) and break (red line) days during the monsoon season over all (a) India and (b) central India along with the seasonal monsoon rainfall (grey histograms) over the respective regions.

IV. Conclusion

This study is aimed at the understating the recent rainfall trends in India from 1901 to 2019 for different seasons and summer monsoon season in particular. Time series analysis and various non-parametric trend analysis scores are used to understand significant trends. The monsoonal rainfall over India as a whole was found to possess positive trend but the variability in seasonal rainfall was observed to be more in the recent 2-3 decades. This infers that the number of extreme rainfall years increased in the recent past. Over the north eastern India which is generally considered as a heavy rainfall region showed a decreasing trend with more number of extreme rainfall years in the recent past. Over the southern India and the central India, the trend in rainfall over the past century was found to be flat and the mean rainfall remained constant over the past century. The MKT was used as a preliminary trend analyzer for obtaining the monotonic trend values at a significance level of 90%. Three regions were found significant as the z-values were higher and the corresponding p-values were less the 0.1. The pre-monsoon rainfall over India and the pre-monsoon and annual rainfall over north west India were found to show strong positive trend as per the MKT. The collected results from the MKT were then put to the test using an innovative trend analysis (ITA) method that has some advantages in terms of graphical representation of data. The regions which showed significant trends were studied using the ITA to verify if the changes in rainfall trends have occurred during the recent times or earlier times. Over India and north west India, most of the excess rainfall years lied above the diagonal line which infers that the rainfall has been increasing in the latter half of the century i.e. post-1960. However, over central India, there were been mixed results of increase/ decrease in rainfall as there were more drought years in the earlier epoch whereas there were more excess years in the recent epoch.

Focusing on the trends in monsoon rainfall over India and central India, the trend lines were positive/ negative over India/central India when studied for the entire 119 years. Central India showed a decreasing trend which may adversely affect a large number of population as large scale agricultural activities as well as important river systems are home to this region. On dividing the entire time series into 30 years slices, it was observed that the rainfall showed a sharp increasing trend from 1901-1950 after which the 30-year trend lines showed a significant decreasing trend. Over the recent 30-year i.e. 1990-2020, the rainfall trend was relatively flatter which infers that the monsoon rainfall and its variability is quite significant on multi-decadal time scales. Another alarming fact from the time series is that there were more number of sharp spikes in the recent 30-40 years with more number of excess/drought anomalous years. The number of spikes were more and quite strong for the central India region with more number of drought years in particular. There has been an increase in the intensity and frequency of deficit years after 1960 over central India in particular. Though there is not much change in the mean seasonal monsoon rainfall over the recent epoch, there has been a drastic increase in the monsoon variability in the form of increases total number of break days. Flood years have been complimented by a greater number of active days where as normal as well as drought years are accompanied by more number of break days. This may pose a challenge for the next epoch for the agricultural sector as well as the sectors involved with the hydrology during the monsoon season.

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7. Manuscript submitted *must not have been submitted or published elsewhere* and all authors must be aware of the submission.

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Acknowledgments

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

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

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

Manuscript Style Instruction (Optional)

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

Structure and Format of Manuscript

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

A research paper must include:

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

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

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

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

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

Format Structure

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

All manuscripts submitted to Global Journals should include:

Title

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

Author details

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

Abstract

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

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

Keywords

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

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

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

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

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

Numerical Methods

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

Abbreviations

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

Formulas and equations

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

Tables, Figures, and Figure Legends

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

Figures

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

Preparation of Eletronic Figures for Publication

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

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

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Tips for writing a good quality Social Science Research Paper

Techniques for writing a good quality homan social science 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 homan social science 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.
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.

19. 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.

20. 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.

21. 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.

22. 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.

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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:

- o Single section and succinct.
- o An outline of the job done is always written in past tense.
- o Concentrate on shortening results—limit background information to a verdict or two.
- o 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?
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Approach:

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

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