P - ISSN : 2722 - 0133
E - ISSN : 2722 - 0141

Indonesian Journal of Applied Environmental Studies

Volume 4 • Number 2 • October 2023

Co-Published by

Pakuan University

Cover Photo : The silvery gibbon (*Hylobates moloch*) Audebert, 1798. Also known as the Javan gibbon, is a lesser ape that is endemic to the Indonesian island of Java, where it inhabits undisturbed rainforests up to an altitude of 2,450 m above sea level. It has been listed Endangered on the IUCN Red List since 2008, as the wild population is estimated to comprise less than 2500 mature individuals (©Robithotul Huda).

Published biannually

P-ISSN: 2722 - 0133 E-ISSN: 2722 - 0141

Indonesian Journal of Applied Environmental Studies

P - ISSN: 2722 - 0133 (printed edition)
E - ISSN: 2722 - 0141 (electronic)
Graduate School of Environmental Management
Pakuan University
Jl. Pakuan, Kotak Pos 425 Bogor
Telp / Fax: (0251) 8320123
Web: www.unpak.ac.id
Email: ml.pasca@unpak.ac.id

The Indonesian Journal of Applied Environmental Studies is co-published by Graduate School of Environmental Management, Pakuan University, Indonesia and Perhimpunan Cendikiawan Pemerhati Lingkungan Indonesia (PERWAKU) in collaboration with Belantara Foundation. It is an open access journal available at: **https://journal.unpak.ac.id/index.php/InJAST/index**

Indonesian Journal of Applied Environmental Studies (InJAST) would like to express its gratitude to the people below for their invaluable services as peer-reviewers on this issue of the journal:

Adi Susilo, M.Sc. (*Indonesia*)
Dr. Chittaranjan Baruah, M.Sc. (*India*)
Dr. Dolly Priatna (*Indonesia*)
Lan Qie, Ph.D. (*United Kingdom*)
Laura D'Arcy, M.Sc. (*United Kingdom*)
M. Nazre Saleh, Ph.D. (*Malaysia*)
Prof. Dr. M. Monirul H. Khan, Ph.D. (*Bangladesh*)
Dr. Rita Retnowati (*Indonesia*)
Dr. Rosadi (*Indonesia*)
Prof. Dr. Wahyu Widiyono (*Indonesia*)
Dr. Yossa Istiadi (*Indonesia*)

InJAST's website and online submission portal is:
https://journal.unpak.ac.id/index.php/InJAST/index

Submissions can also be directed to the Chief Editors at: **injast@unpak.ac.id**

Comments on InJAST's website, reporting portal issues and other issues, should be addressed to the Editorial Manager at: **editor_injast@unpak.ac.id**

InJAST
Volume 4, Number 2, October 2023
Pages: 58-63

P - ISSN: 2722 - 0133
E - ISSN: 2722 - 0141
DOI: 10.33751/injast.v4i2.7851

GUEST EDITORIAL

Environmental land use conflicts and ecosystem services: paper review

ANDI SETYO PAMBUDI*

Directorate for Monitoring, Evaluating, and Controlling Regional Development – National Development Planning Agency (Bappenas), Gedung Bappenas Lantai 9, Jl. H.R. Rasuna Said, Kuningan, Jakarta 12920, Indonesia

*Corresponding author: *andi.pambudi@bappenas.go.id*

Submitted 24 May 2023; Accepted 06 October 2023

BACKGROUND, PROBLEM, PURPOSE, METHODOLOGY

The topic of potential conflicts related to land use involving human activities in a watershed is an important matter to be discussed (Pambudi & Pramujo, 2022). The background of this research is that conditions in mountainous watersheds, agricultural land use causes changes in ecosystem services, with trade-offs between crop production and erosion regulation. Watershed management with an environmental concept often faces problems with different interests among stakeholders. Land-use and land-cover conversion by human activities cause changes in ecosystems and their functions. It encourages researchers to map the effective use of land resources in the context of land management, which is a region-specific policy. Land-use conflicts occur when ecologically vulnerable land is used by human activities, resulting in a contravention between two different goals, namely: sustainable conservation and profitable land-use.

Although several studies have initiated the mapping of land-use conflicts between human activities and conservation, the spatial assessment of land-use conflicts on environmental issues and trade-offs of ecosystem services in agricultural areas has not been fully considered. Paper entitled *"Mapping environmental land use conflict potentials and ecosystem services in agricultural watersheds"*, written by Ilkwon Kim & Sebastian Arnhold (2018) in the journal Science of the Total Environment, 630, 827-838 with doi:10.1016/j.scitotenv.2018.02.176. This paper takes a step further to map land use conflicts between agricultural preferences for food crop production and environmental emphasis on erosion regulation.

The purpose of this study is to map land use, with indicators of measuring conflicts in the value of conservation and agricultural development, through scenarios of the level of erosion hazard on agricultural land. This study applies the land suitability index (LSI) and soil potential to estimate and classify the agricultural land capacity. In addition, it assesses two land management scenarios (i.e., reforestation and annual crop cultivation) to classify trade-offs between ecosystem services and to identify the suitability of policy options for the significant reduction of land-use conflicts in agricultural areas. This study provides input to decision-makers regarding watershed conservation efforts that still consider aspects of the economic needs of agricultural land. The objective of the reviewers is to understand how the concept of mapping the potential conflict of land use in the Haean watershed in South Korea can be applied in Indonesia.

The methodology used is to apply the agricultural land suitability index based on various analytical criteria to estimate the spatial preferences of agricultural activities. To predicting erosion, using the Revised Universal Soil Loss Equation (RUSLE) method and the classification of agricultural land in the watershed is divided into four levels of land use conflict (lowest, low, high, and highest).

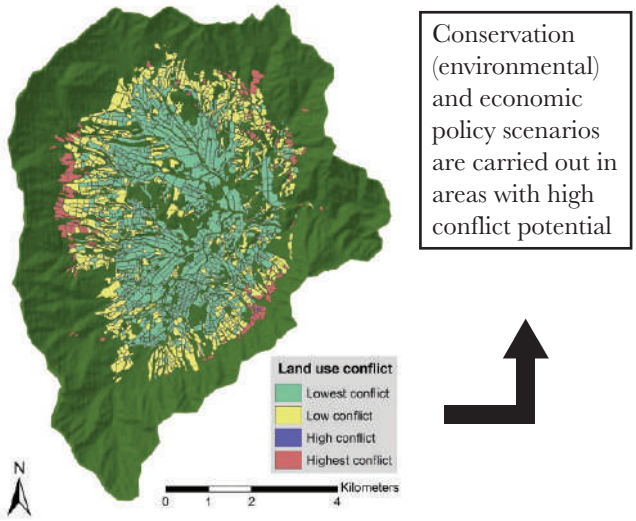
SUMMARY AND FINDINGS

Watersheds (or DAS in Indonesian) are natural ecosystems bounds by ridges with rainwater that falls in the area will flow into rivers which eventually empties into the sea or lake (Pambudi & Kusumanto, 2023; Asdak, 2010; Arsyad 2006; Suripin 2004). In the watershed, there are two areas, namely the water supply area (upstream area) and the water receiving area (downstream area), which are interconnected and affect each other. Halim (2014) stated that the function of the watershed is as a catchment area, water storage, and water distribution area. The low level of formal protection of protected areas is of great concern even though it is significant for sustainable development. Pressures on protected areas and their impacts show great value to communities, both in the surrounding environment and in general (Pambudi, 2020; Cumming, 2016; Watson et al., 2014).

Yi et al. (2018) suggest that with the continued decline of local and global biodiversity and ecosystem services, it is critically important to understand how biodiversity and various ecosystem services interact and how land changes may alter these interactions over time. Land use decisions lead to vulnerability to land-use conflicts. The conflict occurs interpreted as a trade-off between the provision and regulation of ecosystems regarding

agricultural practices. Regulatory services (erosion regulation) to improve water quality are significant for residents in downstream areas, while upstream areas focus on procurement services (harvest production). However, trade-offs between ecosystem services in regional agriculture have not been considered in studies of land-use conflicts. In this study, researchers mapped potential land-use conflicts and identified trade-offs between different ecosystem services in agricultural land. The researcher classified agricultural areas according to the conflicted land use environment and extracted the areas with the highest conflict, where agricultural production capacity was low, causing severe land loss. The classification of conflict areas reflects the degree of trade-off between ecosystem services. Land management programs, which strike a balance between different ecosystem services, remain a challenge in the environment. Identification of priority areas with the highest conflict can increase service capacity to reduce losses in service delivery.

Land use conflict is defined as a situation which stakeholders face a conflict of interest (Pambudi & Pramujo, 2022). Land use conflict defines as a situation in which stakeholders face a conflict of interest in their land to use land resources which causes negative effects (Von der Dunk et al., 2011). Kim and Arnhold's research found that soil loss in agricultural areas in the Haean watershed was estimated at 94,504.2 tons/ha/year, and agricultural suitability of 0.873. The results show that the potential for land-use conflicts is highest in steep areas where reforestation can significantly contribute to soil erosion regulation.



Source: Kim & Arnhold, 2018

Figure 1. Result of land use conflict analysis in Haean Watershed, South Korea.

The study simulates agricultural land management scenarios with the option of converting the area with the highest level of conflict into the forest as much as 7.5% of the total area (Scenario 1) can reduce land loss by 24.6%. When Scenario 2 is carried out, namely by managing the conversion of paddy fields into annual crops in the highest conflict areas by the community, it can reduce land loss by 19.4% more than the current scenario (business as usual). The result can maximize land management plans by extracting spatial priority issues and land use conflicts -versus- conservation as trade-offs for ecosystem services.

Table 1. Comparison of land use composition scenario results.

Business as Usual (BAU)	Scenario 1	Scenario 2
Soil loss 94,504.2 tons/ha/year	Soil loss 67,702.9 tons/ha/year	Soil loss 75,973.2 tons/ha/year
No conversion in agricultural land	Agricultural land converted into a forest	Agricultural land converted into annual crops
Communities get optimal economic benefits, but it is not sustainable	Communities did not have economic benefits, but it is environmentally friendly and sustainable	Communities still have economic benefits, and it is environmentally friendly and sustainable
High potential conflict (between environmental / conservation and economic interests)	Higher potential for conflict (ignoring economic interests)	The potential for conflict is reduced (still considering economic interests)

Source: Processed from the results of Kim 7 Arnhold's analysis, 2018

STRENGTH AND WEAKNESS OF PAPER

The advantage or positive side of this paper is that it has brought up the concept of sustainable development by giving portions to 3 aspects, namely economic, social and environmental. The solution offered from the research results illustrates that there are efforts to reduce potential conflicts between conservation needs and economic and social needs. This study views a larger space than just the environmental aspect as an absolute driver of sustainability, but also other factors, namely the economic. It allows stakeholders to develop the concept of a strategic conservation area as an "ecological and hydrological infrastructure" that becomes a source of ecosystem services, but the aspect of community economic needs is also a concern.

This paper has shown the author's foresight about the effectiveness of policy intervention sites selection, namely to reduce the rate of erosion significantly only need to intervene in areas with the highest potential conflict. It shows that to reduce the erosion rate does not need to change or provide policy interventions in all areas of potential conflict, but only in areas with the highest conflict potential. The mapping of the 3 Scenarios carried out by the author is also sufficient to consider readers to determine or choose the most realistic option, namely by allowing conditions to continue as they are (business as usual), conversion of the highest conflict areas to forests (Scenario 1) and

conversion of conflict areas. The highest is an annual plant. Each option provides information on the risk of the resulting erosion rate as well as the economic and environmental benefits that may be obtained by the community.

Mapping the supply and use of ecosystem services discussed in the paper brings together connections/relationships between socio-economic and environmental (conservation) aspects. By showing the risk of existing erosion rates, the authors have offered a sustainable ecosystem approach through environmentally friendly land resource management without ignoring the needs of communities. Protection of natural ecosystems has a better impact if it is in line with economic aspects, especially concerning ensuring a reduction in erosion rates.

Another positive thing that can be taken is that spatial analysis determines areas of potential conflict (lowest, low, high, highest), enabling policymakers and the community to carry out recovery programs/activities more effectively and focused. The accuracy of determining the location of the policy has an impact on cost, time, and energy efficiency.

One of the weaknesses or negative sides of this paper is the lack of empirical data for input factors, which does not adequately reflect local heterogeneity. In addition, this paper has not considered the aspect of calculating population pressure on land. The assumption used by the author when offering the Scenario 2 option (conversion to annual crops) is that the people's livelihoods are horticulture farmers, whereas the existing ones are agriculture/rice farmers. In addition, to estimate the optimal value of each indicator is also needs various input factors that reflect the local heterogeneity of the watershed. Another weakness of this paper is that it still focuses on reducing the rate of erosion option as the point of analysis, not yet touching on accurate economic calculations. Although limited, this research can visualize the macro spatial distribution of erosion rate calculations and crop production potential (economically profitable) that can help formulate agricultural land management policies in water catchment areas.

The concept of spatial planning and land use change is inseparable from watershed management, which considering the balance of upstream and downstream ecosystems within the identical hydrological boundaries (Pambudi, 2019; Arsyad 2006; Suripin 2004). Watershed management is closely related to the ecosystem approach and hydrological regulation where people or humans are a significant element in it.

CONDITIONS IN INDONESIA

Kim & Arnhold's research (2018) has never been done in Indonesia, but one of the conceptually related studies is the research of Wuryanta & Susanti (2015). Their study conducted at the Keduang Watershed, which is part of the Gajah Mungkur Reservoir Catchment Area, Wonogiri Regency, Central Java. This study assesses the relationship of population/humans to land use upstream, which is prone to erosion. The purpose of the study was to calculate and determine the level of population pressure on agricultural land in the Keduang watershed and each sub-district in the Keduang Sub-watershed. These objectives were obtained by: 1) identifying the area of each sub-district located in the Keduang watershed area; 2) land cover/use analysis, and 3) population analysis which includes population and population growth in each sub-district in the Keduang Sub-watershed.

ANALISIS SPASIAL TEKANAN PENDUDUK TERHADAP LAHAN PERTANIAN DI SUB DAS KEDUANG, KABUPATEN WONOGIRI, JAWA TENGAH

(Spatial Analysis of Population Pressure on Agricultural Land in Keduang Sub Watershed, Wonogiri District, Central Java)

Agus Wuryanta & Pranatisari Dyah Susanti
Balai Penelitian Teknologi Kehutanan Pengelolaan Daerah Aliran Sungai,
Jl.A.Yani, Pabelan PO.BOX 295 Kartasura-Surakarta, Indonesia
e-mail: agus_july1063@yahoo.com dan pranatisari_santi@yahoo.com

Diterima 11 Desember 2014, direvisi 5 Agustus 2015, disetujui 24 Agustus 2015

ABSTRACT

Population pressure on agricultural land is one of the important parameters to determine the level of watershed environment quality. High population pressure on agricultural land in a watershed can lead to land degradation and watershed ecosystems damage. The purpose of research is to calculate and determine the level of population pressure on agricultural land in the sub watershed and in each district in the sub watershed by using Geographic Information System (GIS). Population pressure on agricultural land is calculated by using Soemarwoto's formula (1985). The classification of population pressure on agricultural land is based on the Decree of the Directorate General of Land Rehabilitation and Social Forestry (RLPS.) Ministry of Forestry of Indonesia No. P.04/V-SET/2009. The research was conducted in Keduang sub-watershed which is part of water chatchment area of Gajah Mungkur Reservoir in Wonogiri District, Central Java. The results showed that population pressure on agricultural land in Keduang Sub-watershed is categorized as "bad" with the value of 28.978,16. Girimarto, Jatipurno, Jatiroto, Jatisrono and Sidoharjo districts are categorized as "medium", while Jatiyoso, Kismantoro, Ngadirojo, Nguntoronadi, Purwantoro, Slogohimo and Tirtomoyo districts are categorized as "bad" with the value more than 2.

Keywords: Population pressure, Keduang Sub-Watershed and Geographic Information System (GIS).

ABSTRAK

Tekanan Penduduk (TP) pada lahan pertanian adalah salah satu parameter penting untuk menentukan tingkat kualitas lingkungan suatu Daerah Aliran Sungai (DAS). Tingginya TP pada lahan pertanian pada suatu DAS dapat mengakibatkan penurunan sumber daya lahan dan kerusakan ekosistem DAS. Tujuan penelitian adalah untuk menghitung dan menentukan tingkat TP pada lahan pertanian pada sub DAS dan masing–masing kecamatan pada sub DAS dengan menggunakan perangkat Sistem Informasi Geografis (SIG). Untuk menghitung TP digunakan rumus Soemarwoto (1985). Klasifikasi TP didasarkan pada SK Ditjen RLPS P.04/V-SET/2009. Penelitian dilaksanakan di Sub DAS Keduang yang merupakan bagian dari Daerah Tangkapan Air (DTA) Waduk Gajah Mungkur Kabupaten Wonogiri, Jawa Tengah. Hasil penelitian menunjukkan Tekanan Penduduk (TP) di Sub DAS Keduang dikategorikan jelek dengan nilai TP = 28.978,16. Wilayah kecamatan di dalam sub DAS Keduang yang tekanan penduduknya dalam kategori sedang adalah Kecamatan Girimarto, Jatipurno, Jatiroto, Jatisrono dan Sidoharjo. Wilayah Kecamatan Jatiyoso, Kismantoro, Ngadirojo, Nguntoronadi, Purwantoro, Slogohimo dan Tirtomoyo memiliki nilai TP > 2 dikategorikan jelek.

Kata kunci: Tekanan Penduduk pada lahan (TP), Sub DAS Keduang dan Sistem Informasi Geografis (SIG).

I. PENDAHULUAN

Sub Daerah Aliran Sungai (Sub DAS) Keduang merupakan salah satu Daerah Tangkapan Air (DTA) Waduk Gajah Mungkur di Kabupaten Wonogiri. Berdasarkan hasil penelitian dari JICA (2007), Sub DAS tersebut juga sebagai penyumbang sedimentasi terbesar, yaitu 1.218.580 m³ atau sekitar 38,33% dari total sedimentasi di Waduk Gajah Mungkur. Sedimentasi yang besar sebagai akibat tingginya erosi pada lahan di wilayah Sub DAS Keduang tersebut disebabkan oleh pemanfaatan dan pengelolaan lahan yang tidak sesuai dengan kemampuan dan daya dukung lahan akibat dari peningkatan kebutuhan.

Peningkatan jumlah penduduk terkait erat

Research by Kim & Arnhold (2018) and Wuryanta & Susanti (2015) emphasizes the concept of human ecology as a core part of their research. The basis of human ecology is the pattern of relationships between society as a community and the surrounding environment.

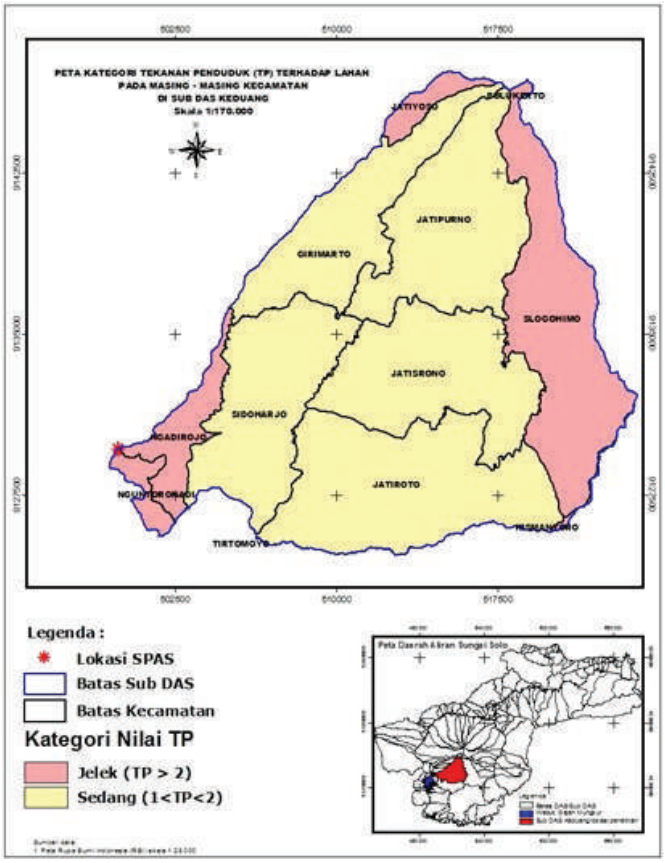
The increase in population is closely related to the increasing need for land, which can lead to the conversion of agricultural land to non-agricultural land so that it has an impact on ecological changes that lead to environmental degradation (Sartohadi, 2008). In addition, Suputra (2012) suggests that population growth causes land-use problems to become more complex and highly competitive. Land-use change that is not well

planned (not taking into account the ability and carrying capacity of the land) can cause various environmental impacts such as erosion, lack of water catchment areas, flooding, river silting, decreased fertility, and land productivity, and others (Harianto, 2002).

Table 2. Population pressure (TP) on land in each sub-district in the Keduang Sub-watershed.

No.	Kecamatan *(Sub District)*	Tekanan Penduduk (TP) *(Population Pressure)*	Klasifikasi *(Classification)*
1	Bulukerto	-	-
2	Girimarto	1,91	Sedang
3	Jatipurno	1,23	Sedang
4	Jatiroto	1,21	Sedang
5	Jatisrono	1,88	Sedang
6	Jatiyoso	5,15	Jelek
7	Kismantoro	386,95	Jelek
8	Ngadirojo	8,46	Jelek
9	Nguntoronadi	12,25	Jelek
10	Purwantoro	3.719,80	Jelek
11	Sidoharjo	1,26	Sedang
12	Slogohimo	2,37	Jelek
13	Tirtomoyo	2.002,86	Jelek
	Sub DAS *Sub watershed*	28.978,16	Jelek

Source: Analysis results of Wuryanta & Susanti, 2015



Source: Wuryanta & Susanti, 2015

Figure 2. Spatial display identification of areas with high population pressure affecting the rate of erosion.

Research conducted by Wuryanta & Susanti (2015) shows spatially the impact of population pressure on land with the recommendation that various conservation efforts and or reduction of population pressure (TP) in the Keduang Sub-watershed of Wonogiri Regency need to be more focused on seven sub-districts, namely: Jatiyoso, Kismantoro, Ngadirojo, Nguntoronadi, Purwantoro, Slogohimo and Tirtomoyo whose level of balance between land area and the population is TP > 2. To get a more accurate TP value in the Keduang Sub-watershed, data collection on the number of residents and farmers recommends being carried out not only in the administrative area but also in the sub-watershed area.

SIGNIFICANT SOLUTIONS (OPINIONS AND SUGGESTIONS)

The results of this research in the Keduang watershed of Central Java would be better if combined with the research of Kim and Arnhold (2018) in the Haean watershed in South Korea, which relates population pressure to land and mapping areas of potential conflict in conservation and socio-economic policies. Kim and Arnhold's research (2018) will complement the accuracy of erosion predictions associated with human activities. The combination of spatial approaches, watershed, economic, and social concepts with the main point in the human aspect will realize a more integrated and comprehensive view of Mapping Priority Land Use Potentials to Sustainable Agricultural Watersheds.

The phenomenon of the downward trend in environmental quality marked by a high rate of erosion underlies the concept of sustainable development, which is a concept that pays great attention to environmental sustainability in line with social and economic needs. Spatial planning that considering the impact of erosion should begin by identifying areas that naturally must be saved (protected areas) to ensure environmental sustainability, and areas that are naturally prone to disasters in the upstream (prone to natural hazards). Thus, spatial planning must begin with the question: how can watershed conservation be sustainable?.

The paper written by Kim & Arnhold (2018) should be equipped with options for the readiness or response of the rice farming community if they have to convert their land to annual crops. have Recommendations given by the researcher have not considering changes in a community culture that may arise. Another suggestion is the need to present the calculation figures for the design costs, advantages, and disadvantages of each scenario, knowing how economically profitable it is for policymakers and the community if they will carry out these scenarios.

The paper will be more comprehensive if equipped with an analysis of sociological and cultural approaches as a follow-up effort to the results of the spatial mapping

done. It is significant because a policy or technical recommendation will not be sustainable without the participation of the community (humans) as the main factor for its success. The reviewer argues, in the future, it is necessary to deepen the science of human ecology to synergize with spatial-technical analysis in non-social science scientific research as carried out by Kim & Arnhold (2018) in the Haean watershed, South Korea, and Wuryani and Susanti (2015) in the Keduang watershed, Indonesia. With the involvement of the human ecological approach, the position and role of human interaction with the environment will become clearer, which also comprehensively examines natural conditions, social organizations, traditions, and the technology that supports them.

CONCLUSION OF THE REVIEW

Natural resources have a dual role, namely as a capital for economic growth (resource-based economy) and at the same time as a life support system. Until now, natural resources is a highly significant role as the backbone of the human economy and will still be relied on in the medium term. On the other hand, economic policies that favor short-term growth have triggered aggressive, exploitative, and expansive patterns of production and consumption, so that the carrying capacity and function of the environment has declined, even leading to severe conditions. The balance of ecosystems and economy with long-term sustainability targets is currently the concern of many researchers, both in Indonesia and globally. Based on these dual functions, natural resources management must always balance to ensure sustainable development. The principles of a sustainable development application in all sectors and regions are the main prerequisite to be internalized into development policies.

The paper written by Kim & Arnhold (2018) in the Haean River Basin, South Korea, is quite helpful if applied in Indonesia to obtain balanced policy directions between conservation (environmental) and socio-economic needs in sustainable watershed management. This research provides input to decision-makers regarding watershed conservation efforts (enhancing environmental carrying capacity) which considers the alignment with the economic needs of agricultural land. Therefore, it suggested changing the title of the existing paper to "Mapping priority land use potentials to sustainable agricultural watersheds."

REFERENCES

Arsyad, S. (2006). *Konservasi Tanah dan Air*. Bogor: IPB Press

Cumming, G. S. (2016). The relevance and resilience of protected areas in the Anthropocene. *Anthropocene, 13: 46–56*. doi:10.1016/j.ancene.2016.03.003

Halim, F. (2014). Pengaruh hubungan tata guna lahan dengan debit banjir pada Daerah Aliran Sungai Malalayang. *Jurnal Ilmiah Media Engineering, 4(1): 45-54*. ISSN: 2087-9334

Harianto, K. (2002). Biaya lingkungan yang terabaikan dalam kebijakan ketahanan pangan. *Prosiding Seminar Tekanan Penduduk, Degradasi Lingkungan dan Ketahanan Pangan. Bogor, 1 Mei 2002*. Bogor: Pusat Studi Pembangunan Pusat Penelitian Institut Pertanian Bogor.

Kim, I., & Arnhold, S. (2018). Mapping environmental land use conflict potentials and ecosystem services in agricultural watersheds. *Science of The Total Environment, 630: 827-838*. doi:10.1016/j.scitotenv.2018.02.176

GoI. (2007). *Law 26 of 2007 concerning Spatial Planning (Undang-undang Nomor 26 Tahun 2007 tentang Penataan Ruang)*. Jakarta: Government of Indonesia

GoI. (1999). *Law 41 of 1999 concerning Forestry (Undang-undang Nomor 41 Tahun 1999 ten¬tang Kehutanan)*. Jakarta: Government of Indonesia

Pambudi, A.S., & Kusumanto, T. (2023). Water resources governance in Indonesia towards environmental sustainability along with social and economic development. In: Triyanti, A., Indrawan, M., Nurhidayah, L., Marfai, M.A. (eds) Environmental Governance in Indonesia. *Environment & Policy, vol 61. Springer, Cham*. https://doi.org/10.1007/978-3-031-15904-6_16

Pambudi, A.S., & Pramujo, B. (2022). Cross-Generation Agrarian Conflict in Indonesia's Palm Land. *Proceedings of the International Conference on Sustainable Environment, Agriculture and Tourism (ICOSEAT). ABSR 26, pp. 828–836*. https://doi.org/10.2991/978-94-6463-086-2_110

Pambudi, A.S. (2022). Balancing infrastructure, ecosystem conservation, and community approaches on integrated development planning of Citarum Watershed. *Indonesian Journal of Applied Environmental Studies, 3(1): 34-41*. https://doi.org/10.33751/injast.v3i1.4209

Pambudi, A. S. (2020). System dynamics modelling of deforestation rate and forest rehabilitation in the upstream of Ciliwung Watershed, Bogor Regency. *Jurnal Perencanaan Pembangunan: The Indonesian Journal of Development Planning, 4(3): 327-346*. https://doi.org/10.36574/jpp.v4i3.121

Pambudi, A.S. (2019). Watershed management in Indonesia: a regulation, institution, and policy review. *Jurnal Perencanaan Pembangunan: The Indonesian Journal of Development Planning, 3(2): 185-202*. https://doi.org/10.36574/jpp.v3i2.74

Sartohadi J, P. F. (2008). Evaluasi potensi degradasi lahan dengan menggunakan analisa kemampuan lahan dan tekanan penduduk terhadap lahan pertanian di Kecamatan Kokap Kabupaten Kulon Progo. *Forum Geografi, 22 (1): 1-12*. DOI: 10.23917/forgeo.v22i1.4921

Suripin. (2004). *Pelestarian Sumber Daya Tanah dan Air*. Yogyakarta: Penerbit ANDI

Von der Dunk, A., Grêt-Regamey, A., Dalang, T., & Hersperger, A. M. (2011). Defining a typology of peri-urban land-use conflicts – A case study from Switzerland. *Landscape and Urban Planning, 101(2): 149–156.* doi:10.1016/j.landurbplan.2011.02.007

Watson, J. E. M., Dudley, N., Segan, D. B., & Hockings, M. (2014). The performance and potential of protected areas. *Nature, 515(7525): 6773*. doi:10.1038/nature13947

Wuryanta, A. & Susanti, P.D. (2015.) Spatial analysis of population pressure on agricultural land in Keduang Sub Watershed,Wonogiri District, Central Java. *E-Journal Penelitian Sosial, 12 (3): 149-162*.

Yi, H., Güneralp, B., Kreuter, U. P., Güneralp, İ., & Filippi, A. M. (2018). Spatial and temporal changes in biodiversity and ecosystem services in the San Antonio River Basin, Texas, from 1984 to 2010. *Science of The Total Environment, 619-620: 1259–1271.* doi:10.1016/j.scitotenv.2017.10.3

InJAST
Volume 4, Number 2, October 2023
Pages: 64-66

P - ISSN: 2722 - 0133
E - ISSN: 2722 - 0141
DOI: 10.33751/injast.v4i2.9661

NEWS, NOTES, & EVENTS

Climate Change and Its Implications on Wildlife Conservation

DOLLY PRIATNA[1,*] and **KATHRYN A. MONK**[2]

[1]Graduate School of Environmental Management, Pakuan University, Indonesia
[2]Biosciences Department, Swansea University, United Kingdom

*Corresponding Author email: *dollypriatna@unpak.ac.id*

The Intergovernmental Panel on Climate Change (IPCC) Synthesis Report (IPCC, 2023), released nearly a year ago, summarized five years of reports on global temperature rises, fossil fuel emissions and climate impacts and emphasised that there was "a rapidly closing window of opportunity to secure a liveable and sustainable future for all." It demonstrated an undeniable scientific consensus about the urgency of the climate crisis, its primary causes, its current devastating impacts − especially on the most climate vulnerable regions − and the irreversible harm that will occur to both the natural world and human society if warming surpasses 1.5°C, even temporarily.

For Indonesia, climate change poses a formidable challenge for its people and its rich terrestrial and marine biodiversity that encompasses such a diverse array of ecosystems ranging from lush rainforests and dry savannas to extensive swamps and coral reefs (Sala et al,. 2000). As the world's fourth most populous nation and the biggest archipelagic country in the world, Indonesia consists of some 17,000 islands, with over 8,000 km of coastline and is therefore extremely vulnerable to the impacts of global climate change. The nation's rich biodiversity, encompassing iconic species such as the Sumatran tiger, orangutan, and Komodo dragon, is intricately linked to the health of its ecosystems. Rising temperatures, changing precipitation patterns, and the increasing frequency of extreme weather events disrupt these ecosystems, leading to shifts in species composition and distribution (Parmesan & Yohe, 2003).

Indonesia is highly vulnerable to long-term changes from sea level rise. Coastal ecosystems, including coastal peat swamps, mangroves, and estuaries, face salt-water encroachment, affecting the breeding and feeding grounds of numerous species of aquatic and terrestrial species (Priatna et al., 2021). The loss of these vital habitats disrupts not only the wildlife dependent on these habitats, but also the numerous local village communities dependent directly on coastal waters for their survival, as well as the larger fishing industries extracting resources for the increasing urban populations. In addition, the very existence of many coastal settlements is under threat, not least, Jakarta, the capital city, where the threat posed by sea-level rise exacerbates the impacts of a combination of groundwater extraction and land subsidence.

Extreme weather events, such as floods, heatwaves, and droughts, are becoming more frequent and intense in Indonesia as in the rest of the world. These events lead to habitat destruction, wildfires, soil erosion, altered water availability, and increased invasive species (Alisjahbana & Busch (2017). The impact on biodiversity can be extensive, affecting species that are not only directly exposed to these events but also those dependent on specific environmental conditions for their subsequent survival.

More persistent and continuous changes in temperature patterns pose significant threats especially to Indonesia's rare habitats, from coral reefs to high mountain tops. Over the past few decades, the country has experienced a discernible increase in mean temperatures. Elevated temperatures can have direct and indirect effects on biodiversity, influencing species' physiology, behaviour, and distribution. Coral reefs, among the most diverse marine ecosystems globally, are especially vulnerable. Indonesia's coral reefs, including those in the Coral Triangle, face the threat of coral bleaching, driven by elevated sea temperatures. The bleaching events not only endanger the rich marine life but also affect the livelihoods of coastal communities dependent on fisheries.

The interconnected nature of ecosystems means that the loss of certain species can have cascading effects throughout the food web. For instance, the decline of pollinator species, crucial for plant reproduction, can lead to a reduction in plant diversity and negatively impact other species dependent on these plants for food and shelter.

Changes in temperature, rainfall patterns, and extreme weather conditions have a direct impact on habitats and food resources. Subsequent changes can include shifts in animal migration patterns (Miller-Rushing et al., 2019), alterations in growing and reproductive seasons, and changes in the geographical distribution of habitats. These changes, in turn, affect food resource availability, wildlife population abundance and distribution, and overall their health levels (Acevedo-Whitehouse & Duffus, 2009). Additionally,

they can influence the patterns of wildlife interaction with other wildlife species and, increasingly, with humans (Abrahms, 2023).

The consequences of biodiversity loss extend of course beyond ecological concerns to encompass economic and social dimensions (Monk & Priatna, 2022). Indigenous and local communities, often deeply connected to the land and sea and directly dependent on natural resources for their livelihoods, face increased vulnerability. Changes in the distribution of fish stocks, alterations in agricultural productivity, and disruptions to traditional practices through habitat loss all contribute to the challenges faced by these communities. Furthermore, the loss of biodiversity undermines the potential for academic and general education and for further applied scientific discoveries, such as genetic resources that could be critical for medicine, agriculture, and industry (Rahman et al., 2023).

In addition immediate ecological and socio-economic impacts, the loss of biodiversity in Indonesia exacerbates the global challenge of climate change itself. Forests, acting as carbon sinks, play a crucial role in mitigating climate change by absorbing and storing carbon dioxide. Indonesia's vast rainforests are, however, under threat from deforestation and degradation, driven by poorly planned and manage logging (Adnan & Dadi, 2023), agricultural expansion, and palm oil production. The release of stored carbon into the atmosphere intensifies the greenhouse effect, contributing to further warming and creating a feedback loop that amplifies the challenges posed by climate change.

Climate change therefore poses significant challenges to Indonesia's, and the world's, conservation and restoration efforts. One major consequence is the exacerbated changes in habitat distribution, already significantly affected by land-use changes brought about by increasing commercial exploitation, that increase the risk of extinction for species unable to move or adapt quickly. Population management becomes more complex due to increased interactions among previously isolated species. Disrupted migration patterns complicate conservation efforts to protect vital pathways and habitats.

This environmental shift introduces considerably more uncertainty into conservation planning and management (Wilkening et al., 2022). Predicting climate projections and impact estimates affects long-term strategies to protect endangered or vulnerable species. Climate change influences disease spread among wildlife and between wildlife and humans, necessitating new disease management approaches in conservation environments. Successful conservation efforts require an adaptive, climate-oriented approach that considers future climate scenarios and land use changes (Johnson et al., 2023).

The global strategy to address climate change's impact on wildlife conservation involves expanding shelter areas, emphasizing microrefugia, microrefugia, environmental gradients, and areas connecting current and future climates (Hannah et al., 2007). Maintaining ecosystem processes through robust conservation strategies is crucial, along with restoring degraded lowland areas for landscape-level climate resilience (Lestari & Priatna, 2020; Pertiwi et al., 2021; Priatna et al., 2022). Literature highlights the importance of management recommendations addressing climate change impacts, including protected areas, invasive species, adaptive management, and conservation facilities (Hannah et al., 2007). However, further research on local-scale interventions is vital. Socio-political factors, particularly weaker governance and lower GDP, contribute to greater species losses due to climate change. International coordination is essential for effective conservation across changing cross-border areas.

Indonesia, as a mega biodiversity country, needs to implement effective conservation strategies to preserve its biodiversity and wildlife in the face of a changing climate. One important strategy is the establishment of biobanks, which can supplement in situ conservation efforts and help preserve genetic diversity. However, current biobanking efforts in Indonesian wildlife are limited and need to be expanded to include neglected taxa and regions (Sushadi, 2023). Furthermore, effective law enforcement measures, such as site-based monitoring networks and responsive government agencies, are crucial in addressing the illegal wildlife trade and protecting nationally protected species (Adhiasto et al., 2023). Also, there is a need for more ambitious ocean-conservation legal standards and policies to protect the ocean and its ecosystems from emerging threats. Lastly, spatial prioritization and expansion of protected areas can maximize environmental values and contribute to meeting post-2020 global biodiversity targets (Pusparini et al., 2023). By implementing these strategies, Indonesia can effectively preserve its biodiversity and wildlife in the face of climate change and human pressures.

Indeed, Indonesia faces a complex challenge, but international collaboration can provide shared knowledge, resources, and technology for more effective conservation measures. Through concerted efforts, Indonesia can protect its biodiversity, ensuring the continued existence of unique ecosystems and the benefits they provide to the nation and the world.

REFERENCES

Abrahms, B., Carter, N. H., Clark-Wolf, T. J., Gaynor, K. M., Johansson, E., Mcinturff, A., Nisi, A. C., Rafiq, K., and West, L. (2023). Climate change as a global amplifier of human–wildlife conflict. *Nature Climate Change, 13(3), 345-353*. https://doi.org/10.1038/s41558-023-01608-5

Acevedo-Whitehouse, K., and Duffus, A. L. J. (2009). Effects of environmental change on wildlife health. *Phil. Trans. R. Soc. B, 364, 3429–3438*. https://doi.org/10.1098/rstb.2009.0128

Adhiasto, D. N., Johnsen, P., Mardiah, S., Exploitasia, I., Giyanto., Fahlapie, P., Andriansyah, M. I., Hafizoh, N., Setyorini, Y. D., Mardhiah, U., and Linkie, M. (2022).A criminal justice response to address the illegal trade of wildlife in Indonesia. *Conservation Letters, 16, e12937*. https://doi.org/10.1111/conl.12937

Adnan, B. A., and Dadi. (2023). Tropical forest conservation efforts as climate change mitigation in Indonesia: A Review. *Interdisciplinary International Journal of Conservation and Culture, 1(2), 80-89*. https://doi.org/10.25157/iijcc.v1i2.3633

Alisjahbana, A. S., and Busch, J. M. (2017). Forestry, Forest Fires, and Climate Change in Indonesia. *Bulletin of Indonesian Economic Studies, 53(2), 111-136*. https://doi.org/10.1080/00074918.2017.1365404

Hannah, L., Midgley, G. F., Andelman, S., Araujo, M. B., Hughes, G. O., Martinez-Meyer, E., Pearson, R., and Williams, P. H. (2007). Protected area design in a changing climate. *Frontiers in Ecology and the Environment, 5(9), 431-438*. https://doi.org/10.1890/1540-9295(2007)5[131:PANIAC]2.0.CO;2

IPCC. (2023). Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. H. Lee and J. Romero (eds.). IPCC: Geneva, Switzerland. https://doi.org/10.59327/IPCC/AR6-9789291691647.

Johnson, J. E., Welch, D. J., van Hooidonk, R., Tracey, D., Chandrasa, G., Molinari, B., Triani, D., Tania, C., and Susanto, H. (2023). Climate change implications for the Arafura and Timor Seas region: assessing vulnerability of marine systems to inform management and conservation. *Climatic Change, 176(88), 1-26*. https://doi.org/10.1007/s10584-023-03554-9

Lestari, N. S., and Priatna, D. (2020). Prinsip-Prinsip Restorasi Ekosistem Hutan Dataran Rendah Lahan Kering. In: Y. Rochmayanto, D. Priatna, & M. Z. Mutaqqin (eds.). Strategi dan Teknik Restorasi Ekosistem Hutan Dataran Rendah Lahan Kering. Bogor: IPB Press. Pp. 32-48.

Miller-Rushing, A. J., Primack, R. B., and Şekercioğlu, C. H. (2019). Conservation Consequences of Climate Change for Birds. In: P.O. Dunn & A.P. Moller (eds.). Effects of Climate Change on Birds. 2nd Edition. Oxford: Oxford University Press. Pp. 295-309.

Monk, K. A., and Priatna, D. (2022). Environmental security and resilience – Indonesia an dglobal challenges. *Indonesian Journal of Applied Environmental Studies, 3(1): 3-15.* https://doi.org/10.33751/injast.v3i1.5215

Parmesan, C., & Yohe, G. (2003). A globally coherent fingerprint of climate change impacts across natural systems. *Nature, 421(6918), 37-42*. https://doi.org/10.1038/nature01286

Pertiwi, N., Tsusaka, T. W., Sasaki, N., and Gunawan, E. (2021). Peatland conservation strategies and carbon pricing possibilities for climate change mitigation in Indonesia: a review. IOP Conf. Ser.: Earth Environ. Sci. 892 012061. https://doi.org/10.1088/1755-1315/892/1/012061

Priatna, D., Suryadi, D., Rochmayanto, Y., and Afandi, I. (2021). Restorasi Ekosistem Hutan Mangrove pada Hutan Lindung sebagai Penyangga Konsesi HTI. In: D. Priatna, Y. Rochmayanto, K. L. Ginoga & M. Z. Mutaqqin (eds.). Strategi dan Teknik Restorasi Ekosistem Hutan Mangrove. Bogor: IPB Press. Pp. 49-57.

Priatna, D., Syaepulloh, I. L., and Ario, A. (2022). Perception and awareness of local Community to a "Green Wall" forest restoration programme in the Gunung Gede Pangrango National Park, Indonesia. *Asian Journal of Conservation Biology, 11(1): 77-83*. https://doi.org/10.53562/ajcb.71349

Pusparini, W., Cahyana, A., Grantham, H. S., Maxwell, S., Soto-Navarro, C., and Macdonald, D. W. (2023). A bolder conservation future for Indonesia by prioritising biodiversity, carbon and unique ecosystems in Sulawesi. *Scientific Reports, 13, 842*. https://doi.org/10.1038/s41598-022-21536-2

Rahman, W., Brehm, J. M., and Maxted, N. (2023). The impact of climate change on the future distribution of priority crop wild relatives in Indonesia and implications for conservation planning. *Journal for Nature Conservation, 73, 126368*. https://doi.org/10.1016/j.jnc.2023.126368

Sala, O.E., Chapin F. S., Armesto, J. J., Berlow, E. L., Bloomfield, J. B., Dirzo, R. H., Huber-Sannwald, E., Huenneke, L., Jackson, R. B., Kinzig, A. P., Leemans, R., Lodge, D. M., Oesterheld, M. I. N., Poff, N. L., Sykes, M. T., Walker, B., Walker, M., and Wall, D. H. (2000). "Global biodiversity scenarios for the year 2100." Science, 287(5453), 1770-1774. https://doi.org/10.1126/science.287.5459.1770

Sushadi, P. S. (2023). The distribution and current state of biobanking in Indonesian wildlife: a systematic review. *Animal Conservation, 26(6), 2023*. https://doi.org/10.1111/acv.12879

Wilkening, J. L., Magness, D. R., Harrington, A., Johnson, K., Covington, S., and Hoffman, J. R. (2022). Incorporating Climate Uncertainty into Conservation Planning for Wildlife Managers. *Earth, 3(1), 93-114*. https://doi.org/10.3390/earth3010007

InJAST
Volume 4, Number 2, October 2023
Pages: 67-76

P - ISSN: 2722 - 0133
E - ISSN: 2722 - 0141
DOI: 10.33751/injast.v4i2.7751

Air quality indices assessment in Artisanal Gold Mining Areas of Zamfara State, Nigeria

BATE, GARBA BARDE[1*], SAM-UKET NWUYI OKORI[2]

[1]Environmental Science Department, Federal University Dutse, Jigawa State, Nigeria
[2]Animal and Environmental Biology Department, Cross River University of Technology, Calabar, Cross River State, Nigeria

Corresponding author: *bategarba@yahoo.com*

Submitted 18 May 2023 ; Accepted 29 October 2023

ABSTRACT

Mining processes contribute significantly to air pollution which is the largest cause of human deaths worldwide. This research was conducted to assess air pollution in three gold mining areas, i.e. Kwali, Maraba, and Duke; and a non–mining area Kadauri in Zamfara State, Nigeria. Monthly measurements of CO, SO_2, and NO_2 were done using Gasman detection instrument (Crowcon–EExias IIC T5), particulates were determined using optical counter, and buffered KI solution was used to measure O_3 while temperature, humidity, and pressure were measured using their respective meters over a period of one year. Air quality indices were calculated using the USEPA (1999) AQI formula, pollutants and meteorological factors relationships were determined using Pearson's correlation and seasonal variation was measured using T–test. The highest and lowest CO were 25.85±7.42 µg/m^3 in Kwali and 12.08±3.32 µg/m^3 in Kadauri respectively, SO_2 was also highest (48.15±12.42 µg/m^3) and lowest (31.74±6.67 µg/m^3) in Kwali and Kadauri respectively. O_3 was highest (151.29±29.74 ppb) and lowest (107.38±21.95 ppb), while PM_{10} was highest (498.37±48.49 µg/m^3) and lowest (319.31±44.86 µg/m^3) in Duke and Kadauri respectively. Air quality parameters generally exceeded the WHO limit while CO, SO_2, and $PM_{2.5}$ had significant difference ($P<0.05$) across sampling stations. Mining areas had hazardous AQI with Duke being the highest (392) and Kadauri had 248 implying an unhealthy atmosphere. Pollutants correlated negatively with humidity and positively with pressure while temperature inversely correlated with NO_2, SO_2 and $PM_{2.5}$. Pollutants concentrations were significantly higher in dry season, hence the use of PPEs, information and regulation of mining activities as well as increased humidity are suggested.

ABSTRAK

Proses penambangan berkontribusi signifikan terhadap polusi udara yang merupakan penyebab kematian manusia terbesar di seluruh dunia. Penelitian ini dilakukan untuk mengkaji pencemaran udara di tiga wilayah pertambangan emas, yaitu Kwali, Maraba, dan Duke; dan kawasan non-pertambangan Kadauri di Negara Bagian Zamfara, Nigeria. Pengukuran bulanan CO, SO_2, dan NO_2 dilakukan dengan menggunakan instrumen pendeteksi Gasman (Crowcon–EExias IIC T5), partikulat ditentukan menggunakan penghitung optik, dan larutan buffer KI digunakan untuk mengukur O_3, sedangkan suhu, kelembaban, dan tekanan diukur menggunakan alat meter masing-masing selama periode satu tahun. Indeks kualitas udara dihitung menggunakan rumus AQI USEPA (1999), hubungan polutan dan faktor meteorologi ditentukan menggunakan korelasi Pearson dan variasi musiman diukur menggunakan uji T. CO tertinggi dan terendah masing-masing sebesar 25,85±7,42 µg/m^3 di Kwali dan 12,08±3,32 µg/m^3 di Kadauri, SO_2 juga masing-masing tertinggi (48,15±12,42 µg/m^3) dan terendah (31,74±6,67 µg/m^3) di Kwali dan Kadauri. O_3 tertinggi (151,29±29,74 ppb) dan terendah (107,38±21,95 ppb), sedangkan PM_{10} tertinggi (498,37±48,49 µg/m^3) dan terendah (319,31±44,86 µg/m^3) masing-masing terdapat pada Duke dan Kadauri. Parameter kualitas udara secara umum melebihi batas WHO, sedangkan CO, SO_2, dan $PM_{2.5}$ memiliki perbedaan yang signifikan ($P<0,05$) antar stasiun pengambilan sampel. Area pertambangan memiliki AQI berbahaya dimana Duke merupakan yang tertinggi (392) dan Kadauri memiliki 248 yang mengindikasikan atmosfer yang tidak sehat. Polutan berkorelasi negatif dengan kelembaban dan positif dengan tekanan, sedangkan suhu berkorelasi terbalik dengan NO_2, SO_2 dan $PM_{2.5}$. Konsentrasi polutan jauh lebih tinggi pada musim kemarau, oleh karena itu disarankan untuk menggunakan APD, informasi dan peraturan kegiatan penambangan, serta peningkatan kelembaban.

Keywords: *air pollutants, air quality index, gold mining, meteorological factors, Zamfara State*

INTRODUCTION

Air is an essential factor necessary for life as it is a mixture of gases such as oxygen which supports respiration, nitrogen which provides nutrients for plant growth and forms bases for amino acids, and carbon dioxide which is important in photosynthesis (Belnap 2013). Tropospheric air composition in an unpolluted environment contains about 78.08% N_2, 20.95% O_2, 0.93% Ar, 0.039% CO_2 and 0.003% water vapour, particulate matter and others (Strobel et al., 2009). Polluted air may have higher or lower percentage compositions of these individual elements and the presence of other elements or compounds as well which brings about an imbalance in the normal function of the entire ecosystem and the overall quality of individual life

(Manisalidis et al., 2020). Zawar–Reza and Sponken–Smith (2005) defined air pollution as the contamination of the atmosphere by physical, chemical or biological agents that produce measurable adverse effects on man, animals, vegetation or materials. Common air pollutants consist of CO, NO, NO_2, SO_3, tropospheric O_3, hydrocarbons and dispersed particles most of which come from internal combustion engines of heavy industrial machines, gas flaring in oilfields, volcanic eruptions mining and other anthropogenic activities (Francis et al., 2017; Fawole et al., 2019; Abaje et al., 2020). Air pollution has been identified as the largest cause of human fatalities worldwide, accounting for about 8.8 million deaths each year, and reducing by 3 years the average life expectancy of man (Lelieveld et al., 2020; Rajveer and Puneeta, 2021).Gold mining processes entail excavation through drilling, digging or blasting, followed by processing through washing, grinding, smelting etc and lastly refining, all of which lead to serious air pollution (Ratan, 2005).

Air quality index (AQI) is a scheme that transforms the overall weighted individual values of air quality parameters into a single value or a set of values (Tiwari, 2015). AQI is used as a warning system to the public based on measurements of gases such as CO, SO_2, NO_2, ground level O_3 and particulate matter ($PM_{2.5}$ and PM_{10}) in the atmosphere. It shows the extent of air pollution at different locations and helps in their temporal and spatial comparison. This study was carried out to assess the air quality of artisanal gold mining areas in Zamfara state, Nigeria.

MATERIALS AND METHODS

The Study Area

Zamfara State of Nigeria is located between latitude 12°10'N and 12°167'N, and longitude 06 °15'E and 06°250'E, with a total area of 39,762 square kilometers (Asuquo and Bate, 2020). Air quality parameters of three gold mining areas namely Kwali (05°45.49'E to11°59.66'N), Duke (06°19.56'E to12°21.45'N), Maraba (06°22.43'E to12°20.26'N) and a non mining area: Kadauri (06°08.71'E–12°13.56'N) were assessed. Figure 1 shows the map of the study area.

Air Quality Parameters Analysis

Air quality parameters; CO, SO_2 and NO_2were measured monthly during working hours using an automatic handheld Gasman detection instrument (Crowcon–EExias IIC T5) at purposefully selected locations within each mining site over a period of twelve months covering both dry and wet seasons according to Adekunle et al. (2020). Particulate matter ($PM_{2.5}$ and PM_{10}) were determined using a portable handheld optical particle counter which detects particles' size and

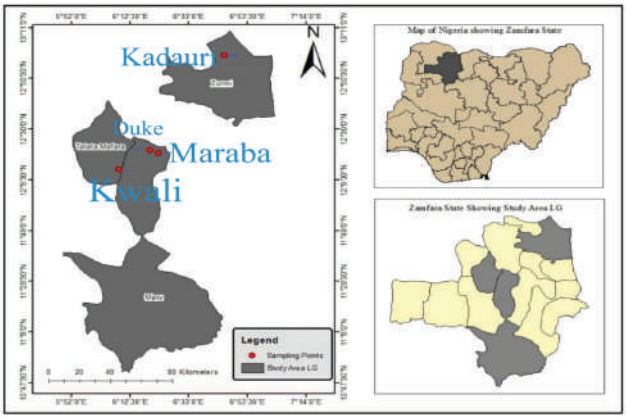


Figure 1. Map of Zamfara State, Nigeria showing the Sampling Locations

amount by measuring the amount of light scattered as they passed through a beam of light. Ozone was determined using buffered potassium iodide solution method developed by Byers and Saltzman (1958) where 1% buffered KI was used for trapping O_3,as it reacts with iodine in neutral buffer solution (Benavent et al., 2022). Weather elements; temperature, humidity, pressure were also measured using their respective meters.

All chemicals used in this research were of analytical grade and strict guidelines were followed in handling them during the experiment to avoid errors while the experiments were replicated to ensure accuracy and reliability of data. All utensils used were washed with water and liquid soap, rinsed in distilled water and dried before use while standard potassium iodide solution was always freshly prepared when needed according to Abdulraheem and Adekola (2011).

Air Quality Index Calculation

Air quality index was calculated using the USEPA (1999) AQI formula:

$$AQI = \frac{Ih - Il}{Ch - Cl}(C - Cl) + Il \quad (1)$$

Where:
C= concentration of the pollutant
Ch = concentration breakpoint that is ≥ C
Cl = concentration breakpoint that is ≤ C
Ih = index breakpoint corresponding to Ch
Il = index breakpoint corresponding to Cl

For multiple pollutants, AQI is the highest value obtained for each pollutant using the formula above (Kanchan et al., 2015). Table 1 shows the concentration breakpoints and corresponding index breakpoints of some air pollutants while table 2 shows the category and interpretation of each index breakpoint according to USEPA (1994).

Table 1. Air pollutants with their Concentration and Index Breakpoints

CO (µg/m^3)	SO_2 (µg/m^3)	NO_2 (µg/m^3)	$PM_{2.5}$ (µg/m^3)	PM_{10} (µg/m^3)	O_3 (ppb)	AQI
Cl-Ch	*Cl-Ch*	*Cl-Ch*	*Cl-Ch*	*Cl-Ch*	*Cl-Ch*	*II-Ih*
0.0-4.4	0-35	0-53	0.0–12.0	0–54	0–54	0–50
4.5-9.4	36-75	54-100	12.1–35.4	55–154	55–70	51–100
9.5-12.4	76-185	101-360	35.5–55.4	155–254	71–85	101– 150
12.5-15.4	186-304	361-649	55.5–150.4	255–354	86–105	151–200
15.5-30.4	304-604	650-1249	150.5–250.4	355–424	106–200	201–300
30.5-40.4	605-804	1250-1649	250.5–350.4	425–504	201–404	301–500
40.5-50.4	805-1004	1650-2049	350.5–500.4	505–604	405–504	

Source: USEPA,1994

Table 2. Air Quality Index Categories and Interpretation

Air Quality Index	Category
0-50	Good
51-100	Moderate
101-150	Unhealthy for sensitive groups
151-200	Unhealthy
201-300	Very Unhealthy
301-500	Hazardous

Statistical Analysis

Variations in mean air quality parameters across sampling locations were determined using analysis of variance (ANOVA), relationship between air quality parameters and weather elements were determined using Pearson's correlation analysis while Student T–test was used to determine the seasonal differences in air quality parameters.

RESULT AND DISCUSSION

Mean Air Quality Parameters of Artisanal Gold Mining Areas of Zamfara, Nigeria Compared with WHO Limit

Mean Carbon monoxide concentration was highest (25.85±7.42 µg/m^3) in Kwali mining area and lowest (12.08±3.32 µg/m^3) in Kadauri with a significant difference (P<0.05) among them and all values exceeded the WHO limit, likewise the highest and lowest SO_2 were 48.15±12.42 µg/m^3 in Kwali and 31.74±6.67 µg/m^3 in Kadauri respectively with only Kadauri complying with the WHO limit. NO_2,$O_3$and PM_{10} did not fifer significantly (P>0.05) across sampling stations but were all above the WHO limit. Atmospheric pressure was highest (3786.36±283.71 N/m^2) in Kwali and lowest(3391.61±269.17 N/m^2) in Kadauri with a significant difference (P<0.05) among sampling stations while temperature, pressure and humidity did not differ significantly (P>0.05). Mean air quality parameters of gold mining areas in Zamfara state, Nigeria compared with the World Health Organization standards for air quality are presented in table 3.

All the criteria air pollutants analysed in this study were above the WHO limit for air quality except for SO_2 in the Control. This implies a serious health risk for the miners and inhabitants of the area as air pollution is seen as one of the biggest environmental threats to human health (WHO, 2005). Air pollution is particularly dangerous because of the route of exposure which allows the pollutants to cross over through the alveoli into the bloodstream that takes them straight to the heart from where they are pumped into the systemic circulation before coming to the liver for detoxification as the liver

Table 3. Mean Air Quality Parameters of Gold Mining Areas and Control in Zamfara, Nigeria compared with WHO Limits

Parameters	Kwali	Duke	Maraba	Kadauri	P-Value	WHO Limit
CO (µg/m^3)	25.85±7.42	19.19±5.83	16.40±4.62	12.08±3.32	P<0.05	7
SO_2 (µg/m^3)	48.15±12.42	44.39±4.31	45.94±5.87	31.74±6.67	P<0.05	40
NO_2 (µg/m^3)	113.29±47.85	91.48±42.61	103.49±39.97	97.74±41.48	P>0.05	10
$PM_{2.5}$ (µg/m^3)	304.72±121.21	297.15±87.64	273.38±91.37	197.53±78.15	P<0.05	5
PM_{10} (µg/m^3)	479.33±46.82	498.37±48.49	432.11±39.50	319.31±44.86	P>0.05	15
O_3 (ppb)	134.91±33.58	151.29±29.74	110.32±22.34	107.38±21.95	P>0.05	100
Temperature (^{0}C)	33.29±11.06	34.48±13.81	31.37±12.49	33.86±45.83	P>0.05	–
Pressure (N/m^2)	3786.36±283.71	3611.82±291.03	3519.36±305.13	3791.61±269.17	P>0.05	
Humidity (%)	35.09±4.76	38.14±4.93	36.94±8.82	36.05±6.68	P>0.05	

receives only about 25% of cardiac output (Søren and Mauro, 2013; Ghorani–Azam, 2016). The non mining area (control) atmosphere which is about 20 kilometers away from the mining areas was found to be highly polluted and this could be due to high mobility of air pollutants as they are not limited to regional boundaries (Marks and Miller, 2022) and can extend several thousands of kilometers and cause harm away from the point sources (Abaje et al., 2020). Similar results were obtained by Bhanu et al. (2014) in their analysis of

particulate and gaseous pollutants in Jharia coal mines of Dhanbad district, India where they found out that all the pollutants exceeded the prescribed national ambient air quality standards (NAAQS) and showed significant spatial variation while higher concentrations were observed around coal mine areas compared to other areas. They described mining as a leading industry causing fatal injuries and other chronic health problems such as black lung disease among miners and nearby communities.

Carbon monoxide is a non–irritating but very poisonous, colorless and odorless gas, common sources of which include incomplete combustion of organic matter, metallurgical operations etc (Ibush et al., 2022). Due to the similarity of its physico-chemical properties and that of O_2, CO is easily absorbed into the circulatory system and it exerts its toxic effects by reacting with haemoglobin to form Carboxyhaemoglobin (COHb) which blocks oxygen receptor sites and limits the amount of oxygen transported to tissues by the haemoglobin, resulting in cardiovascular, developmental and other effects (Bilska-Wilkosz et al., 2022). Mean CO concentration was highest in Kwali during this research which may be due to the fact that it's the most active mining area. SO_2 is formed from the burning of organic matter and smelting of sulphur–containing mineral ores, exposure to which has been linked to respiratory diseases such as bronchospsm, pneumonitis, irritation to the eyes, nose, throat etc especially among sensitive groups (Shofi and Hamzah, 2022). It is a colorless gas with strong pungent odor that easily dissolves in water to form sulphuric acid in the atmosphere, a major component of the acid rain which damages structures, vegetation and animals, it also forms sulphate aerosols which reflect sunlight into space and act as condensation nuclei, making clouds more reflective and having a significant effect on global and regional climate (Haradhan, 2014). SO_2 concentration was highest in Kwali mining area which may not be unconnected to the activity there while in the Control area it was below the WHO limit, indicating lower risk for the inhabitants there. NO_2 is a reddish brown poisonous gas that is formed during combustion, it reacts with water to form nitric acid which is another component of the acid rain that is highly corrosive (Debbie et al., 2010). It is the main ingredient in the formation of photochemical smog reducing visibility while exposure at high concentrations causes painful inflammation of the lungs which may lead to cancer and eventually death if not treated (Maduna and Tomašić, 2017; Javed et al., 2021). The highest concentration of NO_2 in Zamfara gold mining areas during this research was in Kwali which tells further the volume and complexity of activities going on in the area which exposes the inhabitants to the hazards of air pollution.

A mixture of solid particles such as dust and liquid droplets with associated adsorbed organic chemicals and reactive metals which comes in different shapes and sizes in the atmosphere is referred to as the Particulate matter (PM_{10} and $PM_{2.5}$) (Robert and Gökhan, 2018). PM_{10} are coarse particles whose diameter is generally 10 µM and below while $PM_{2.5}$ include fine and ultrafine particles with a diameter of 2.5 µM and below both of which are emitted from excavation, transportation and processing of gold ores and from the complex reactions of chemicals such as SO_2, NO_2 and metals in the atmosphere (Duarte et al., 2022). $PM_{2.5}$ followed the trend of the gaseous pollutants with the highest mean concentration in Kwali and lowest in Kadauri while the case was not so with PM_{10} where the highest mean concentration was in Duke gold mine which signify that particle sizes and composition differ with the type and intensity of activities in an area. $PM_{2.5}$ and PM_{10} fundamentally differ in their chemical compositions, processes of formation, atmospheric residence time, modification and removal as the latter include dust from construction and mining activities, pollens and fragments of organic matter while the former is made from combustion of fuel and other chemical reactions in the atmosphere (Seinfeld and Pandis, 2006; Gieré and Querol, 2010). Exposure to particulate matter generally has been linked to adverse health effects such as lung and heart diseases, $PM_{2.5}$ particularly is responsible for the greatest proportion of air pollution related health effects as it can enter the bloodstream through the walls of the alveoli, causing acute and chronic bronchitis, irregular heartbeat, decreased lung function, cancer, worsening respiratory conditions such as asthma and eventually death while PM_{10} is associated with coughing and sneezing, difficulty in breathing and long term exposure leads to respiratory mortality (Du et al., 2016; Mark and David, 2020). Tropospheric Ozone is formed by a series of complex cycles of photochemical reactions of oxides of Nitrogen (NO_X) and volatile organic compounds (VOCs) in the atmosphere and the catalytic oxidation of CO by NO_X (Finlayson-Pitt and Pitts Jr., 1993; Sillman, 2003). The emission of these gases through the use of heavy equipments and vehicles as well as the use of O_3 in treatment of acid mine drainage and purifying water for dust suppression and washing of ores and minerals leave behind a high O_3 concentration in the troposphere exposure to which causes damage and inflammation to respiratory tract tissues, cardiovascular diseases, damage to plant cells and inability to photosynthesize, leading to reduction in yield (Philip and Clive, 2002; Lim et al., 2019). O_3 concentration was highest in Duke mining area and it was lowest in Kadauri the non–mining area though the difference was not significant which could be as a result of dispersion as Dayana et al. (2014) reported that higher values occurred downwind due to the

transport of precursors. Temperature, pressure and humidity did not significantly differ among sampling stations, they are influenced by and they also influence other weather elements such as sunshine, rainfall etc (Frances and Chika, 2017). In essence, the studied air quality parameters and weather elements put together, constitute a serious threat to the health and well-being of the inhabitants of the study area as human activities trigger the release of atmospheric pollutants in higher than usual concentrations leading to reduced air quality and in turn poor health conditions such as cough and sneezing, asthma, pulmonary and cardiac diseases or even death (Kathrin et al., 2017). Ecosystem functions and services are not exempted from the severe adverse effects of atmospheric pollution as SO_2 and NO_x cause acidification beyond normal range of pH, leading to death of aquatic organism, stunted growth in plants and general low productivity (Kalender and Alkan, 2019). Nitrogen also causes eutrophication, leading to bloom in growth of some organisms and changes in species diversity, and consequently a disruption in both the aquatic and terrestrial ecosystems (Xi et al., 2018) When it leach into the ground or surface water, Nitrogen is consumed by man and other organisms the excess of which restricts oxygen transport in the bloodstream and is very harmful to infants and young livestock, a situation known as blue baby syndrome (Ward et al., 2018). Tropospheric O_3 enters plant stomata, oxidizing leaves and spikes leading to non-availability of green surfaces for photosynthetic activities thereby limiting plant growth and lower yields in agricultural crops (Sumitra et al., 2022). The presence of particulate matter in measures beyond the recommended limits can also adversely affect visibility and photosynthesis/food production by forming a shield to the incoming solar radiation which is the energy used by green plants for photosynthesis.

Air Quality Indices of Gold Mining Areas in Zamfara, Nigeria during the Study

The highest air quality index observed was 392 in Duke mining area while the lowest was 248 in Kadauri while Kwali and Maraba mining areas had AQI of 369 and 324 respectively. Figure 2 presents the air quality indices of the gold mining areas during the study.

All the mining areas had air quality indices in the hazardous category while the non mining area had a very unhealthy AQI which could be attributed to dispersion and atmospheric transportation of substances (Marks and Miller, 2022). The high AQI in the region implies a grave danger and health risk to the inhabitants as many respiratory diseases such as respiratory infections, chronic obstructive pulmonary disease, bronchiectasis, asthma, idiopathic pulmonary fibrosis, lung cancer etc are directly associated with it. Sarmadi et al. (2021) reported that AQI of some industrial and densely populated capital cities across the world differed significantly before and after 2020 with the latter period having lower AQI due to COVID-19 restrictions that cut down on industrial activities. The quality of air or level of pollution is closely linked to the activities and meteorological data in an area as Bălă et al. (2021) described it as a silent killer that hides around us, representing one of the biggest risk factors for human health. Mondal et al. (2020) in their spatio-temporal variation of air pollutants analysis in Jharia Coalfield, India found out that coal mines were the major sources of air pollution in the area, it was also revealed that the AQI of the coal mine affected area was nearly 1.5 times higher than that of the non-mining areas. Transportation is a major contributor to the poor air quality index in the area as the mining activities involve moving the ores from excavation to processing points and movements of humans as well as working materials. The transport sector has been estimated to be responsible for approximately 45% of NOx emission, high quantity of greenhouse gases (GHGs) and particulate matter as a result of fossil fuel combustion and dust from heavy vehicular movements (Nnaji et al., 2023).

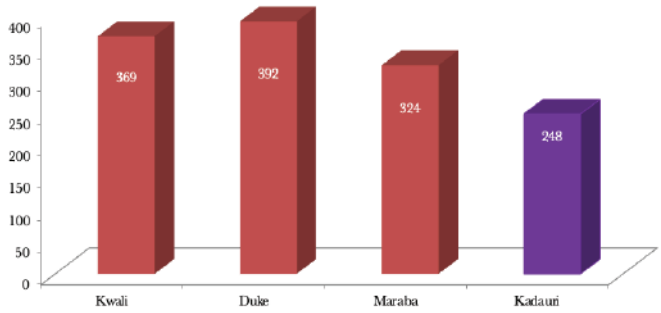


Figure 2. Air Quality Indices of Gold Mining Areas and Control in Zamfara State, Nigeria during the Study

Relationship between Air Quality Parameters in the Study Area

There was a negative relationship between humidity and all other air quality parameters measured with the highest r–value being –0.91 in CO and the lowest was –0.43 in NO_2 while atmospheric pressure had positive correlation with all the parameters, highest r–value of which was1.00 in its relationship with CO and the lowest was 0.59 in NO_2. Temperature had strong positive relationship with O_3 (r=0.59), weak positive relationships with CO and PM_{10} (r=0.05) and negative relationships with NO_2, SO_2 and $PM_{2.5}$ (r=–0.48, –0.35 and –0.08 respectively). Table 4 is a correlation matrix showing the relationship between pairs of air quality parameters in the study area.

Table 4. Correlation Matrix showing the Relationship between Air Quality Parameters

Name	Humid.	O_3	Temp.	NO_2	CO	Press.	SO_2	$PM_{2.5}$	PM_{10}
Humidity	1								
O_3	-0.76	1							
Temperature	-0.44	00.59	1						
NO_2	-0.43	-0.19	-0.48	1					
CO	-0.91	0.65	0.05	0.62	1				
Pressure	-0.92	0.68	0.07	0.59	1	1			
SO_2	-0.55	0.53	-0.35	0.46	0.82	0.83	1		
$PM_{2.5}$	-0.69	0.75	-0.08	0.31	0.86	0.88	0.96	1	
PM_{10}	-0.68	0.83	0.05	0.14	0.8	0.83	0.9	0.98	1

Humidity reduces significantly the level of air pollution, it prevents air pollutants from dispersing into the atmosphere by trapping them close to the ground (Mokoena et al., 2020) hence the negative correlation between humidity and all other pollutants obtained in this research which also implies that miners are safer under humid conditions with all other factors held constant. Humidity however, makes the air damp and uncomfortable while it encourages the development of molds, mildews, bacteria, viruses and other allergens in the atmosphere (Mendell et al., 2011). The positive relationship between air pollutants and atmospheric pressure could be due to the increased vertical mixing and decreased horizontal dispersion that come along with increase in pressure as observed by Guicai et al., (2018) in their work on weather systems and air quality where they reported that an inland high pressure led to temperature inversion and low horizontal wind speed which favour the increase in air pollutants. Liu et al. (2020) reported significant negative correlation between air pollutants and wind speed, precipitation and relative humidity while positive correlation was observed with pressure in their study of air pollution and meteorological conditions. They posited that air pollution and alterations in pollutant concentration are significantly influenced by meteorological conditions and a systematic understanding of this relationship is required for a scientific air pollution management policies formulation. Chao and Min (2022) reported that temperature has obvious effects on air pollutants, they observed a positive linear relationship between air pollutants and temperature in their work on atmospheric pollutants and meteorological factors where increased temperature makes it conducive for vertical flow as well as the diffusion of pollutants. The negative relationships of NO_2, SO_2, $PM_{2.5}$ and temperature in this research could be accounted for by the fact that air pollutants absorb radiant energy thereby affecting the surrounding temperature (Pawar et al., 2023), although meteorological factors do not act in isolation but are in constant multiple and complex reactions with one another and with air pollutants in the atmosphere (Daniel, 2008; Grigorieva and Lukyanets, 2021). Negative relationship between ambient air temperature and gaseous pollutants was also observed by Okimiji et al. (2021) and they explained that conversion of these pollutants to ozone which happens with increased temperature and vertical dispersion regime was responsible for the inverse relationship.

Seasonal Variation of Air Quality Parameters in the Study Area

The mean wet and dry season concentrations of Carbon monoxide were 20.14±2.38 and 32.47±51(μg/m^3) respectively, SO_2 wet and dry seasons concentrations were 39.93±3.62 and 43.05±3.48 (μg/m^3) respectively both of which were significantly different ($P<0.05$) while NO_2 concentrations were 104.81±3.95 and 106.78±2.68 (μg/m^3) respectively, though with no significant difference ($P>0.05$) but dry season concentration was higher. Mean atmospheric pressure during the wet and dry seasons were 3799.38±81.86 and 3421.07±89.62 (N/m^2) respectively while humidity was 49.89±5.83 and 33.75±3.90%respectively with the wet season having significantly higher values. Seasonal variations of the mean air quality parameters of the study area are presented in figure 4.

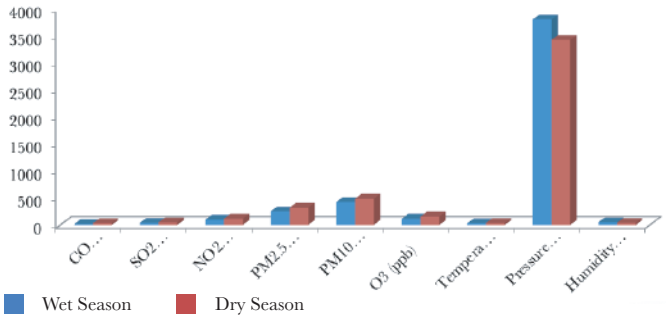


Figure 3. Seasonal Variation of Air Quality Parameters

Air pollutants' dry season concentrations were generally significantly higher than those of the wet

season which may be attributed to higher relative humidity and washout by rainfall which reduces re–suspension of particulates as reported by Oji and Adamu (2020) where they observed lower levels of pollutants under conditions of increased precipitation, higher humidity and lower temperature compared to the dry season and concluded that these meteorological factors have washout or scavenging effect on the pollutants. Similar result was obtained by Eghomwanre et al. (2022) in their research on air pollutants concentration and health risk assessment around residential areas in Benin City, Nigeria and they attributed the higher dry season concentrations to higher temperatures, leading to the downward movement of pollutants and higher ground level concentrations. Onuorah et al. (2019) added that adsorption of water vapour onto particles is enhanced by increase in relative humidity brought about by rainfall during the wet season, leading to settling and dry deposition of particles. Measures that increase humidity in the mining area such as groundwater harvesting, artificial rain etc will be useful in reducing atmospheric pollution particularly during the dry season.

CONCLUSION

Air quality parameters in the mining areas and control site were found to be above the WHO limits except for SO_2 in the control, the mining areas had higher pollutant values with a significant difference in CO, SO_2, and $PM_{2.5}$ across sampling stations indicating the impact of mining activities on air pollution in the areas which can manifest in incidences such as acid precipitation, cardiovascular diseases etc. The AQI of the mining areas were all in the hazardous category while that of the non–mining area was very unhealthy implying serious health risks for the miners and inhabitants of these places. Humidity had a negative correlation with all air quality parameters, the highest of which (–0.91) was in CO which could be due to the washout effect of rain hence miners and inhabitants are at less risk during high humidity. Atmospheric pressure had positive correlation with all air pollutants which was attributed to increased vertical mixing and decreased horizontal dispersion, temperature was inversely correlated with NO_2, SO_2 and $PM_{2.5}$ which could be due to radiant energy absorption by these pollutants as well as the conversion of gaseous pollutants to O_3 which comes with increased temperature and vertical dispersion. There was a significant difference ($P<0.05$) in air pollutants concentrations between seasons with the dry season having higher values which could be attributed to high humidity brought about by rainfall and its actions in the atmosphere. In essence, meteorological factors do not act in isolation but are in constant multiple and complex reactions with one another and with air pollutants in the atmosphere. It is therefore recommended that information and regulation of mining processes should be done to emit less pollutants and make the work safer, the use of personal protective equipments (PPEs) should be encouraged and miners should limit their duration of exposure to these pollutants, provision of first aid kits and other essential services is also important as some of the issues are acute and require emergency attention. Also, measures should be taken to increase humidity in the mining area such as groundwater harvesting and artificial rain especially during the dry season.

REFERENCES

Abaje I. B., Bello Y. and Ahmad S. A. (2020). A Review of Air Quality and Concentrations of Air Pollutants in Nigeria. *Journal of Applied Science and Environmental Management 24(2): 373–379*. DOI:10.4314/jasem.v24i2.25

Abdulraheem A. M. O. and Adekola F. A. (2011). Air Pollution: A Case Study of Ilorin and Lagos Outdoor Air. In: José O. (Eds.), *Indoor and Outdoor Air Pollution*. IntechOpen doi:www.10.5772/1436

Adekunle A., Arowolo T. A., Adeyemi O. M. and Kolawole O. A. (2020). Estimation of Thermal Comfort Parameters of Buiulding Occupants Based on Comfort Index, Predicted Mean Vote, and Predicted Percent of Dissatisfied People in the North–West Zone of Nigeria. *International Journal of Advances in Engineering and Management 2(5): 809–826*. DOI:10.35629/5252-0205809826

Asuquo F. E. and Bate G. B. (2020). Bioaccumulation of Heavy Metals in Mangoes (*Mangifera indica L.*) found in the Vicinity of Gold Mining Sites of Zamfara State, Nigeria. *Journal of Environmental Chemistry and Ecotoxicology 12(1): 45–58*. DOI:10.5897/JECE2020.0464

Bălă G. P., Râjnoveanu R. M., Tudorache E., Motisan R. and Oancea C. (2021). Air Pollution Exposure—the (In)visible Risk Factor for Respiratory Diseases. *Environmental Science and Pollution Research 28: 19615–19628*. https://doi.org/10.1007/s11356-021-13208-x

Belnap J. (2013). *Crusts Biological: Reference Module in Earth Systems and Environmental Sciences*. Elsevier.

Benavent N., Mahajan A. S., Li Q., Cuevas C. A., Schmale J., Angot H., Jokinen T., Quéléver L. L. J., Blechschmidt A., Zilker V., Richter A., Serna J. A., Garcia-Nieto D., Fernandez R. P., Skov H., Dumitrascu A., Simões P. P., Abrahamsson K., Bucci S., Duetsch M., Stohl A., Beck I., Laurila T., Blomquist B., Howard D., Archer S., Bariteau L., Helmig D., Hueber J., Jacobi H., Posman K., Dada L., Daellenbach K. and Saiz-Lopez A. (2022). Substantial Contribution of Iodine to Arctic Ozone Destruction. *Nature Geoscience 15(10): 770–773*. doi.org/ 10.1038/s41561-022-01018-w

Bhanu P., Madhoolika A. and Siddharth S. (2014). Assessment of Air Pollution around Coal Mining Area: Emphasizing on Spatial Distributions, Seasonal Variations and Heavy Metals, using Cluster and Principal Component Analysis. *Atmospheric Pollution Research 5(1): 79–86*. https://doi.org/10.5094/APR.2014.010

Bilska-Wilkosz A., Górny M. and Iciek M (2022). Biological and Pharmacological Properties of Carbon Monoxide: A General Overview. *Oxygen 2: 130–151*. https://doi.org/10.3390/oxygen2020012

Byers H. D. and Saltzman B. E. (1958). Determination of Ozone in Air by Neutral and Alkaline Iodide Procedures. *American Industrial Hygiene Association Journal19(3): 251–257*. doi: 10.1080/00028895809343585.

Chao C. and Min B. (2022). Correlation Analysis of Atmospheric Pollutants and Meteorological Factors based on Environmental Big Data. *International Journal of Contents 18(1): 17–26*. https://doi.org/10.5392/IJoC.2022.18.1.017

Daniel A. V. (2008). *Fundamentals of Air Pollution*, Elsevier Academic Press.

Dayana M. A., Elba C. T., Felipe N. P. (2014). Time–series Analysis of Surface Ozone and Nitrogen Oxides Concentrations in an Urban Area at Brazil. *Atmospheric Pollution Research 5(3): 411–420*. https://doi.org/10.5094/APR.2014.048.

Debbie J. J., Gary A., Marie-Eve H., Regula R. and Frank J. K. (2010). Nitrogen dioxide. In: WHO Guidelines for Indoor Air Quality: Selected Pollutants. Geneva: World Health Organization; https://www.ncbi.nlm.nih.gov/books/NBK138707/

Du Y., Xu X., Chu M., Guo Y. and Wang J. (2016). Air Particulate Matter and Cardiovascular Disease: The Epidemiological, Biomedical and Clinical Evidence. *Journal of Thoracic Diseases 8(1):E8–E19*. doi: 10.3978/j.issn.2072-1439.2015.11.37

Duarte J., Castelo B. J., Rodrigues F., Vaz M. and Santos B. J. (2022). Occupational Exposure to Mineral Dust in Mining and Earthmoving Works: A Scoping Review. *Safety 8(1):9*. https://doi.org/10.3390/safety8010009

Eghomwanre A. F., Oguntoke O., Taiwo O. M. and Ukpebor E. E. (2022). Air Pollutants Concentration and Health Risk Assessment around Residential Areas in Benin City, Nigeria.*Journal of Materials and Environmental Science 13(9): 1081–1100*.

Fawole O. G., Cai X., Abiye O. E. and MacKenzie A. R. (2019). Dispersion of Gas Flaring Emissions in the Niger Delta: Impact of Prevailing Meteorological Conditions and Flare Characteristics. *Environmental Pollution 246:284–293*. DOI:10.1016/j.envpol.2018.12.021

Finlayson-Pitt B. J. and Pitts Jr. J. N. (1993). Atmospheric Chemistry of Tropospheric Ozone Formation: Scientific and Regulatory Implications. *Air and Waste 43(8): 1091–1100*. https://doi.org/10.1080/1073161X.1993.10467187

Frances A. and Chika C. O. (2017). Study of the Variation in Weather Parameters in some selected Cities in Southern Nigeria. *COOU Journal of Multidisciplinary Studies 1(1): 122–132*.

Francis C. I., Alexander I.O., Njoku P.C. and Alinnor J. I. 2017(). Ambient Air Quality Assessment of Orlu, Southern Nigeria. *Journal of Applied Sciences 17(9):441–457*. DOI:10.3923/jas.2017.441.457

Ghorani–Azam A., Riahi–Zanjani B. and Balali–Mood M. (2016). Effects of Air Pollution on Human Health and Practical Measures for Prevention in Iran. *Journal of Research in Medical Science 21: 65*. doi:10.4103/1735-1995.189646

Gieré R. and Querol X. (2010). Solid Particulate Matter in the Atmosphere. *Elements 6: 215–222*. DOI: 10.2113/gselements.6.4.215

Grigorieva E. and Lukyanets A. (2021). Combined Effect of Hot Weather and Outdoor Air Pollution on Respiratory Health: Literature Review. *Atmosphere 12(6): 790*. https://doi.org/10.3390/atmos12060790

Guicai N., Shigong W., Steve H. L. Y., Jixiang L., Yuling H., Ziwei S., Jinyan W. and Jiaxin W. (2018). Impact of Low-pressure Systems on Winter Heavy Air Pollution in the Northwest Sichuan Basin, China. *Atmospheric Chemistry and Physics 18(18): 13601–13615*. https://doi.org/10.5194/acp-18-13601-2018

Haradhan K. M. (2014). Chinese Sulphur Dioxide Emissions and Local Environment Pollution. *International Journal of Scientific Research in Knowledge 2(6): 265–276.* http://dx.doi.org/10.12983/ijsrk-2014-p0265-0276

Ibush L., Milazim S. and Naim B. (2022). Monitoring of Air Pollution on the Premises of the Factory Sharrcem–L.L.C. *International Journal of Computer Science and Network Security 22(10): 214–223*. https://doi.org/10.22937/IJCSNS.2022.22.10.28

Javed A., Aamir F., Gohar U. F., Mukhtar H., Zia-Ui-Haq M., Alotaibi M. O., Bin-Jumah M. N., Marc V. R. A. and Pop O. L. (2021) The Potential Impact of Smog Spell on Humans' Health amid COVID-19 Rages. *International Journal of Environmental Research in Public Health 18(21): 11408*. doi:10.3390/ijerph182111408.

Kalender S. S. and Alkan G. B. (2019). Air Pollution. In: Hussain C. (eds) Handbook of Environmental Materials Management. Springer, Cham. https://doi.org/10.1007/978-3-319-73645-7_77

Kancahan K., Amit K. G. and Pramila G. (2015). A Review on Air Quality Indexing System. *Asian Journal of Atmospheric Environment 9(2): 101–113*. https://doi.org/10.5572/ajae.2015.9.2.101

Kathrin R., Christopher J. K., Kurt L., Naama L., Janine F., Manabu S., Pascale S. J. L., Senchao L., Fobang L., Anna T. K., Kira Z., Fangxia S., Rossella S., Bettina W., Iris B., Joachim S., Michael G. W., Albert D., Detlef S. and Ulrich P. (2017). Air Pollution and Climate Change Effects on Allergies in the Anthropocene: Abundance, Interaction and Modification of Allergens and Adjuvants. *Environmental Science and Technology 51(8): 4119–4141*. https://doi.org/10.1021/acs.est.6b04908

Lelieveld J., Pozzer A., Pöschl U., Fnais M., Haines A. and Münzel T. (2020). Loss of Life Expectancy from Air Pollution compared to other Risk Factors: A Worldwide Perspective. *Cardiovascular Research, 116(11): 1910–1917*. https://doi.org/10.1093/cvr/cvaa025

Lim C. C., Hayes R. B., Ahn J., Shao Y., Silverman D. T., Jones R. R., Garcia C., Bell M. L. and Thurston G. D. (2019) Long-Term Exposure to Ozone and Cause-Specific Mortality Risk in the United States. *American Journal of Respiratory and Critical Care Medicine, 200(8):1022–1031*. doi: 10.1164/rccm.201806-1161OC

Liu Y., Zhou Y. and Lu J. (2020). Exploring the Relationship between Air Pollution and Meteorological Conditions in China under Environmental Governance. *Scientific Reports 10(1): 14518*. doi:10.1038/s41598-020-71338-7

Maduna K. and Tomašić V. (2017). Air Pollution Engineering. *Physical Sciences Reviews 20160122*. DOI: 10.1515/psr-2016-0122

Manisalidis I., Stavropoulou E., Stavropoulos A. and Bezirtzoglou E. (2020). Environmental and Health Impacts of Air Pollution: A Review. *Frontiers in Public Health 8*: https://doi.org/10.3389/fpubh.2020.00014

Mark R. M. and David E. N. (2020) Air Pollution and Cardiovascular Disease: Car Sick. *Cardiovascular Research 116(2): 279–294*. https://doi.org/10.1093/cvr/cvz228

Marks D. and Miller M. A. (2022). A Transboundary Political Ecology of Air Pollution: Slow Violence on Thailand's Margins. *Environmental Policy and Governance 32(4): 305–319*. https://doi.org/10.1002/eet.1976

Mendell M. J., Mirer A. G., Cheung K., Tong M. and Douwes J. (2011). Respiratory and Allergic Health Effects of Dampness, Mold, and Dampness-related Agents: A Review of the Epidemiologic Evidence. *Environmental Health Perspectives 119(6):748–756*. doi: 10.1289/ehp.1002410.

Mokoena K. K., Ethan C. J., Yu Y. and Quachie A. T. (2020). nteraction Effects of Air Pollution and Climatic Factors on Circulatory and Respiratory Mortality in Xi'an, China between 2014 and 2016. *International Journal of Environmental Research and Public Health 17(23): 9027*. doi:10.3390/ijerph17239027.

Mondal S., Singh G. and Kumar M. J. (2020). Spatio-temporal Variation of Air Pollutants around the Coal Mining Areas of Jharia Coalfield, India. *Environmental monitoring and assessment 192(6): 405*. doi:10.1007/s10661-020-08324-z

Nnaji C. C., Chibueze C. and Afangideh C. B. (2023). The Menace and Mitigation of Air Pollution in the Built Environment: A Review. *Nigerian Journal of Technology 42(1): 12–29*.

Oji S. and Adamu H. (2020). Correlation between Air Pollutants Concentration and Meteorological Factors on Seasonal Air Quality Variation. *Journal of Air Pollution and Health 5(1): 11–32*.

Okimiji O. P., Techato K., Simon J. N., Tope-Ajayi O. O., Okafor A. T, Aborisade M. A. and Phoungthong K. (2021). Spatial Pattern of Air Pollutant Concentrations and their Relationship with Meteorological Parameters in Coastal Slum Settlements of Lagos, Southwestern Nigeria. *Atmosphere 12(11):1426*. https://doi.org/10.3390/atmos12111426

Onuorah C. U., Leton T. G. and Momoh O. L. Y. (2019). Temporal Variability of Particulate Matter in Urban Area of Port Harcourt, Nigeria. *Asian Journal of Advanced Research and Reports, 7(2) 1–7*. https://doi.org/10.9734/ajarr/2019/v7i230175

Pawar B., Garg L., Caruana R. J., Buttigieg S. C. and Calleja N. (2023). Analysing Relationship between Air Pollutants and Meteorological Parameters using TRA,PCA & CA: A Concise Review. *Environmental Pollution and Climate Change 7: 327*. DOI:10.4172/2573-458X.1000327

Philip C. and Clive M. (2002). Hazardous Chemicals Handbook (Second Edition), Butterworth-Heinemann, Oxford.

Rajveer K. and Puneeta P. (2021). Air Pollution, Climate Change and Human Health in Indian Cities: A Brief Review. *Frontiers in Sustainable Cities 3*: https://doi.org/10.3389/frsc.2021.705131

Ratan R. T. (2005). *Surface and Underground Excavations–Methods, Techniques and Equipments*, Taylor & Francis Group, Leiden.

Robert B. H. and Gökhan M. M. (2018). Particulate Matter Air Pollution: Effects on the Cardiovascular System. *Frontiers in Endocrinology 9*: https://doi.org/10.3389/fendo.2018.00680

Sarmadi M., Rahimi S., Rezaei M., Sanaei D. and Dianatinasb M. (2021). Air Quality Index Variation Before and After the Onset of COVID-19 Pandemic: A Comprehensive Study on 87 Capital, Industrial and Polluted Cities of the World. *Environmental Science Europe 33: 134*. https://doi.org/10.1186/s12302-021-00575-y

Seinfeld J. H. and Pandis S. N. (2006). *Atmospheric Chemistry and Physics: From Air Pollution to Climate Change*. John Wiley and Sons, New York, USA.

Shofi N. and Hamzah H. (2022). Environmental Health Risk Assessment of Sulfur dioxide (SO2) at Workers around in Combined Cycle Power Plant (CCPP). *Heliyon*. https://doi.org/10.1016/j.heliyon.2022.e09388

Sillman S. (2003). Tropospheric Ozone and Photochemical Smog In: Heinrich D. H. and Karl K. T. (Eds), *Treatise on Geochemistry, pp 407–431*. Pergamon Press, https://doi.org/10.1016/B0-08-043751-6/09053-8.

Søren M. and Mauro B. (2013). Interactions of the Heart and the Liver. *European Heart Journal 34(36): 2804–2811*. https://doi.org/10.1093/eurheartj/eht246

Strobel D. F., Atreya S. K., Bézard B., Ferri F., Flasar, F. M., Fulchignoni M., Lellouch E. and Muller-Wodarg I. (2009). Atmospheric Structure and Composition in Brown R. H. Eds. *Titan from Cassini-Huygens. Springer Science*, New York DOI:10.1007/978-1-4020-9215-2_10

Sumitra P. K., Anushree B. D., Cyaria G. and Chandra G. (2022). Effects of Ozone on Plant Health and Environment: A Mini Review. *Research Journal of Agricultural Science 13(3): 612–619*.

Tiwari P. (2015). Computational Methods Of Air Quality Indices: A LiteratureReview. *IOSR Journal of Environmental Science, Toxicology and Food Technology 1(5): 46–49*.

United States Environmental Protection Agency (USEPA) (1994). Measuring Air Quality: The Pollutant Standards Index. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, USA.

United States Environmental Protection Agency (USEPA) (1999). Guidelines for Reporting of Daily Air Quality Index (AQI). Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, USA.

Ward M. H., Jones R. R., Brender J. D., de Kok T. M., Weyer P. J., Nolan B. T., Villanueva C. M. and van Breda S. G. (2018). Drinking Water Nitrate and Human Health: An Updated Review. *International Journal of Environmental Research in Public Health 15(7):1557*. https://doi.org/10.3390/ijerph15071557

Xi C., Yan-hua W., Chun Y., Wei Z., Zu-cong C., Hao Y. and Xiao H. (2018). Atmospheric Nitrogen Deposition Associated with the Eutrophication of Taihu Lake. *Journal of Chemistry, 4017107*. https://doi.org/10.1155/2018/4017107

Zawar–Reza P. and Sponken–Smith R. (2005). Air Pollution Climatology In: Oliver J. E. (Eds.), *Encyclopedia of World Climatology (pp 21–33)*. Springer, Netherlands. DOI:10.1007/1-4020-3266-8_7

InJAST
Volume 4, Number 2, October 2023
Pages: 77-84

P - ISSN: 2722 - 0133
E - ISSN: 2722 - 0141
DOI: 10.33751/injast.v4i2.8897

Benefit analysis of the implementation of Environmental Management System (EMS) ISO 14001:2015 in a tyres industry

RUTI NURUL HIDAYATI*, SODIKIN, NURHASANAH

Magister Program of Environmental Studies, Open University, Jl. Cabe Raya, Pondok Cabe, Pamulang, South Tangerang 15418, Banten, Indonesia

Corresponding author: *ruti.nurul@gmail.com*

Submitted 15 September 2023 ; Accepted 9 November 2023

ABSTRACT

Environmental management has an important role in PT. Elang Perdana Tyres Industry (PT. EPTI). The company has been implementing a standard of ISO 14001:2015 to implement its environmental management. Environmental Management System (EMS) ISO 14001:2015 implemented consistently and effectively, provides several benefits that can enhance environmental performance in the company. The objectives of this research are 1) to identify the benefits of the implementation of EMS ISO 14001:2015, and 2) to analyze the relationship between the benefits of the implementation of EMS ISO 14001:2015 and the environmental performance of EMS. Primary data was collected from field observations, interviews with respondents, and questionnaire survey. Secondary data was obtained from company profile, and organizational structure, as well as documents of ISO 14001:2015. This research explained that the benefits of the implementation of the Environmental Management System (EMS) ISO 14001:2015 are enhancing company reputation, enhancing customer satisfaction, enhancing employee motivation, and reducing production costs. The main benefit for the company, based on the questionnaire result of 100 respondents that determined from Slovin formula, is enhancing company reputation (93 respondents). Besides, this research also explains that the implementation of EMS ISO 14001:2015 has strong relationship with the environmental performance EMS ISO 14001:2015 (coefficient of regression 0,717). Therefore, the benefits of the implementation of the Environmental Management System (EMS) ISO 14001:2015 are enhancing company reputation, enhancing customer satisfaction, enhancing employee motivation, and decreasing production costs have a strong relationship with environmental performance EMS ISO 14001:2015 in PT. EPTI. Benefit analysis of the implementation of EMS ISO 14001:2015 is needed to inform the company about the importance of benefits that can be obtained for improving the implementation of EMS ISO 14001:2015. The benefits obtained by the company will attract and motivate the company to improve the performance of EMS ISO 14001:2015. Even these benefits will further motivate continuous improvement that has an impact on effective environmental management in reducing negative environmental impacts and supporting sustainable development as a whole.

ABSTRAK

Pengelolaan lingkungan mempunyai peranan penting di PT. Elang Perdana Tyres Industry (PT. EPTI). Perusahaan telah menerapkan standar ISO 14001:2015 untuk menerapkan pengelolaan lingkungannya. Sistem Manajemen Lingkungan (EMS) ISO 14001:2015 yang diterapkan secara konsisten dan efektif, memberikan beberapa manfaat yang dapat meningkatkan kinerja lingkungan di perusahaan. Tujuan penelitian ini adalah 1) mengidentifikasi manfaat penerapan EMS ISO 14001:2015, dan 2) menganalisis hubungan manfaat penerapan EMS ISO 14001:2015 dengan kinerja lingkungan EMS. Data primer dikumpulkan dari observasi lapangan, wawancara terhadap responden, dan survei kuesioner. Data sekunder diperoleh dari profil perusahaan, dan struktur organisasi, serta dokumen ISO 14001:2015. Penelitian ini menjelaskan bahwa manfaat penerapan Sistem Manajemen Lingkungan (EMS) ISO 14001:2015 adalah meningkatkan reputasi perusahaan, meningkatkan kepuasan pelanggan, meningkatkan motivasi karyawan, dan mengurangi biaya produksi. Manfaat utama bagi perusahaan berdasarkan hasil kuesioner terhadap 100 responden yang ditentukan dari rumus Slovin adalah meningkatkan reputasi perusahaan (93 responden). Selain itu penelitian ini juga menjelaskan bahwa penerapan EMS ISO 14001:2015 mempunyai hubungan yang kuat dengan kinerja lingkungan EMS ISO 14001:2015 (koefisien regresi 0,717). Oleh karena itu, manfaat penerapan Sistem Manajemen Lingkungan (EMS) ISO 14001:2015 adalah meningkatkan reputasi perusahaan, meningkatkan kepuasan pelanggan, meningkatkan motivasi karyawan, dan menurunkan biaya produksi mempunyai hubungan yang kuat dengan kinerja lingkungan EMS ISO 14001:2015 di PT. EPTI. Analisis manfaat penerapan EMS ISO 14001:2015 diperlukan untuk memberikan informasi kepada perusahaan mengenai pentingnya manfaat yang dapat diperoleh untuk perbaikan penerapan EMS ISO 14001:2015. Manfaat yang diperoleh perusahaan akan menarik dan memotivasi perusahaan untuk meningkatkan kinerja EMS ISO 14001:2015. Bahkan manfaat-manfaat tersebut akan semakin memotivasi perbaikan berkelanjutan yang berdampak pada pengelolaan lingkungan hidup yang efektif dalam mengurangi dampak negatif terhadap lingkungan dan mendukung pembangunan berkelanjutan secara keseluruhan.

Keywords: *benefits analysis, company reputation, environmental management system, environmental performance, ISO 14001:2015*

INTRODUCTION

Population growth, industrial development, and technological progress can appear environmental problems are more complex (Widiyono, 2022). Decreasing of natural resources excessively with addition of chemical containment in economic activities can also impact resources environmental alteration. It is because economic activities can generate waste beside their product (Ramadan et al., 2015). Waste management is not effective yet can decrease environmental quality like pollution and material damage related the environment aspects. All parties such as government, environmentalists, researchers, and companies, increasingly have concern with global environmental issues because the environmental quality alteration from pollution (Utomo, et al., 2021). There are many advanced and innovative programs involved the Indonesian government agencies, NGOs, industrial and consulting firms, and several universities across the archipelago in co-producing of pioneering approaches to national environmental management that related with environmental management support systems, enhancing environmental law capabilities, improving compliance with environmental regulations standards and requirements (Monk, 2020). Besides that, various scientific disciplines from many countries must create networks and collaborations in further research in efforts to find solutions to environmental problems (Priatna & Monk, 2021).

Decreasing of environmental quality will obtain decreasing natural resources quality that can impact limitation of availability natural resources that can explore by company to meet community needed. Increasing of company awareness will enhance the environmental management and prevention pollution. (Haholongan, 2016) had research to explain that the company attempt to enhance awareness of environmental management of their employee with the important of environmental preservation. It is because the company need to enhance company reputation, equal with environmental aspect compliances. Enhancement of company reputation will give positive response from the customer so demand of product will be increase.

Environmental Management System (EMS) must be implemented effectively in order to reduce negative impact of environmental damage. Corrective action needed order that to take the EMS action did not comply yet with ISO 14001:2015, so that environmental damage will be managed more effectively (Kojra et al., 2020). Implementation of ISO 14001:2015 will obtain many benefits to the company by reducing environmental pollution, enhancing environmental performance, enhancing regulation compliances, reducing environmental risk, and as marketing tools to enhance company reputation (Kamalia et al., 2020). It is make positive value to the company and can obtain company motivation to enhance environmental performance in order to increase company profit (Sari & Kamalia, 2019). Therefore, benefit analysis of implementation is needed to find out the benefits of EMS implementation to increase environmental performance. The objectives of this research are 1) Identifying benefits from the implementation of EMS ISO 14001:2015 in PT. Elang Perdana Tyres Industry (PT. EPTI), 2) To analysis the relationship between benefits of implementation of EMS ISO 14001:2015 and the environmental performance of EMS ISO 14001:2015.

METHODS

Research Location

The research was conducted in PT. Elang Perdana Tyres Industry (PT. EPTI), Sukahati Village, Branta Mulia Industrial Estate, Bogor Regency. PT. EPTI is a foreign investment company from Dubai. This company was operated since 1997 with their product are radial tyres, bias tyres and bias belted tyres with various brand according the order from customers. Their own brand, Accelera and Forceum, is exported to 90 countries worldwide. The location of PT. Elang Perdana Tyres Industry location can be seen in Figure 1.

(Source: Google Map, 2023)

Figure 1. Location of PT. Elang Perdana Tyres Industry in Bogor Regency (Source: Google Map, 2023)

Data Sources

This research using quantitative descriptive method. Data used in this research consist of primary data and secondary data.

Primary data

Primary data that is collected is obtained from field observations, interview the respondents and distribute the questionnaire. The respondents that are interviewed consist of personnel HSE Department (Manager, Supervisor and Administration staff) that manage EMS ISO 14001:2015 in this company. Questionnaire of benefits EMS ISO 14001:2015 was distributing to 100 respondents that are consist of various level of employee.

Secondary data

Secondary data that are collected obtained from company profile, organizational structure, waste management data and ISO 14001 documents. These secondary data were used to find out implementation of EMS ISO 14001:2015 that obtain benefits in company.

Research Method

This research consists of five step of activities, there are documentation studies, arrange research instrumentation, collecting data, data analysis, and deciding relationship between benefits of the implementation of EMS ISO 14001:2015 and environmental performance EMS ISO 14001:2015. The steps of activities can be followed in Figure 2.

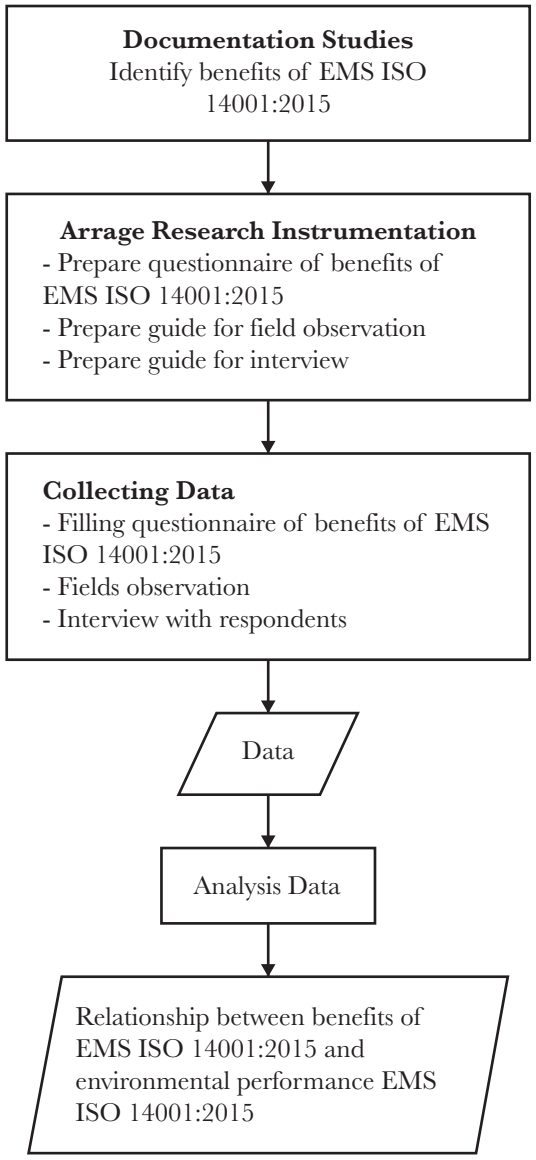


Figure 2. Flow chart of the research.

The first step of this research (documentation studies) started with identifying the benefits of implementation EMS ISO 1400:2015. Thus, identification of benefits from implementation EMS ISO 14001:2015 consists of enhancing company reputation, enhancing customer satisfaction, enhancing employees motivation, and reducing production cost. The second step of this research was arrangement questionnaire as research instrument. This questionnaire contains about benefits of implementation EMS ISO 14001:2015. Besides that, researcher also arranged observation and interview guidance. All these instrument claims to obtain information about benefits of implementation EMS ISO 14001:2015. Third step was collected the data from the instruments. The respondents of this research are employees of the company in PT. EPTI. Data that was collected had been managed and analyze to get information about benefits of implementation EMS ISO 14001:2015. The last step was describing the output of benefits from implementation EMS ISO 14001:2015 from questionnaire, and analyzed the relationship between benefits of the implementation EMS ISO14001;2015 and environmentalpeerformance of EMS ISO 14001:2015.

Sampling Method

This research method is descriptive quantitative with sampling method using questionnaire as the main instrument. Respondents are employee of PT. EPTI. The total number of employee of this company is 2.000 employees, consist of operator that working in three shifts. This research using simple random sampling that each of population unit has same probability to be choosen. Researcher decided the number of sample using Slovin formula (Paramita, 2009).

$$n = \frac{N}{1 + Ne^2}$$

Note:
n= Amount of sample
N= Population
Ne= Degree of accuracy sampling method maximum 10%

based on this formula, the number of samples:

$$n = \frac{2000}{1 + 2000 \times (10\%)^2}$$

$$= 92{,}2 \sim 100 \text{ samples}$$

RESULTS AND DISCUSSION

Identify Benefits from the Implementation of EMS ISO 14001:2015

PT. Elang Perdana Tyres Industry has ISO 14001:2015 certification that explain environmental management for implementing Environmental Management System (EMS). EMS need consistent attempt to comply the standard. Company claims of

board of director and internal audit program can obtain EMS implementation effectively (Erwin, 2021). Motivation from board of director can perhaps increase employee competencies in environmental aspects, energy efficiency program, and hazardous waste management. This attempt can obtain contribution to EMS implementation to achieve goal of environmental performance. These environmental performances can obtain benefits to the company, like reducing production cost, enhance company reputation, enhance employee motivation and enhance customer satisfaction (Abrori et al., 2018). According to questionnaire data from 100 respondents, explain many benefits from the implementation of EMS ISO 14001:2015 in this company (Table 1).

Table 1. Benefits of Implementation EMS ISO 14001:2015

Benefits of Implementation EMS ISO 14001:2015	N of Respondents
Company reputation	93
Customer satisfaction	82
Employee motivation	72
Reduce production cost	78

Respondent's perception shows that the most benefits from the implementation EMS ISO 14001:2015 is enhancing company reputation (93 respondents), while the lowest benefits of implementation EMS ISO 14001:2015 in this company is enhancing employee motivation (72 respondents) (Tabel 1). Questionnaire data analysis on the benefits of implementation EMS ISO 14001:2015 can be seen in Figure 3.

Figure 3 explains that most respondents understand and know that the implementation of EMS ISO 14001:2015 will benefit the company. They had awareness that benefits of implementation EMS ISO

Figure 3. Questionnaire data analyses on the benefits of implementation EMS ISO 14001:2015.

14001:2015 is enhance company reputation. Besides, they also aware benefits implementation EMS ISO 14001:2015 consist of enhance customer satisfaction, enhance employee motivation and reduce production cost. Therefore, it is important to analyse of environmental performance implementation EMS ISO 14001:2015 in PT. EPTI.

Relationship between Benefits of Implementation and Environmental Performance of EMS ISO 14001:2015

Questionnaire data about the benefits of implementation of EMS ISO 14001:2015 had statistical test with instrumentation tests, linear regression tests, feasibility model tests, and classic assumption test. This kind of test is conducted to help in deciding feasible or not feasible data to use in further analysis.

Validity test

A validity test about the benefits of implementation EMS ISO 14001:2015 is conducted using Pearson Correlation (in SPSS software) with a significance level of 5%. This test useful to decide whether the data feasible or not feasible to use. The result of the validity test can be seen in Table 2.

Table 2. Result of validity test on benefits of The implementation of EMS ISO 140012:015

		Company reputation	Customer satisfaction	Employee motivation	Reduce cost production	Environmental performance
Company reputation	Pearson Correlation	1	.998**	.999**	.998**	.283**
	Sig. (2-tailed)		0,000	0,000	0,000	0,004
	N	101	101	101	101	100
Customer satisfaction	Pearson Correlation	.998**	1	.997**	.998**	.397**
	Sig. (2-tailed)	0,000		0,000	0,000	0,000
	N	101	101	101	101	100
Employee motivation	Pearson Correlation	.999**	.997**	1	.998**	.616**
	Sig. (2-tailed)	0,000	0,000		0,000	0,000
	N	101	101	101	101	100
Reduce cost production	Pearson Correlation	.998**	.998**	.998**	1	.587**
	Sig. (2-tailed)	0,000	0,000	0,000	0,000	0,000
	N	101	101	101	101	100
Environmental performance	Pearson Correlation	.283**	.397**	.616**	.587**	1
	Sig. (2-tailed)	0,000	0,000	0,000	0,000	
	N	100	100	100	100	100

Besides, the researcher also had validity test using OLS with criteria test, if R count > R table, data is valid, if R count < R table, data is not valid (Matondang, 2009). Validity test results can be seen in Table 3.

Table 3. Validity test results using OLS.

	Company reputation	Customer satisfaction	Employee motivation	Reduce cost production
R Count	0,286	0,400	0,619	0,590
R Table	0,1966	0,1966	0,1966	0,1966
	V	V	V	V

Note: V= Valid

Results of the validity test based on Pearson Correlation and OLS explain that dependent variables of the benefits of implementation EMS SML ISO 14001:2015 are valid. Result of validity test using Pearson Correlation explain that the significance value < 5% even result of validity test using OLS explains that R count > R table, data is valid.

Line regression

Linear regression was used to determine the relationship between the benefits of implementation of EMS ISO 14010:2015 and the environmental performance of EMS ISO 14001:2015. Determination coefficient used to measure how much influences both variables. The value of R2 closer to 0 explains that the limitation of capability independent variable to describe dependent variable. The value of R2 closer to 1 explains that the independent variable obtain almost all information that needed to predict dependent variable. Coefficient variable using adjusted R-Square because amount of independent variable more than 1. Coefficient value of determination can bee seen in Table 4.

Table 4. Linear regression of the benefits of Implementation EMS ISO 14001:2015.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	853	0,728	0,717	0,06840	0,728	63,566	4	95	0,000	2,090

Based on Table 4, adjusted R-Square 0,717 explains that the influences proportion independent variable benefits of implementation EMS ISO 14001:2015 towards dependent variable environmental performance EMS ISO 14001:2015 is 71.7%. This result describe that independent variable benefits of implementation EMS ISO 14001:2015 have strong influences to predict dependent variable environmental performance EMS ISO 14001:2015, however, 28.3% is influenced by other variables beyond of analysis. According to the coefficient range in the research conducted by Pratomo and Astuti (2015), relationship between independent variable benefits of implementation EMS ISO 14001:2015 towards dependent variable environmental performance EMS ISO 14001:2015 is strong. It is describe that independent variable benefits of implementation EMS ISO 14001:2015 contribution have strong influences simultaneously towards dependent variable environmental performance EMS ISO 14001:2015.

Test of feasibility model

Two test of feasibility model conducted in this research are as follows:

1. Significance test of individual parameter T-test

   T-test in linear regression is used to estimate regression model accurately to describe trend of independent variable to influence dependent variable. Parameter is estimated in linear regression are constant and slope. The test results can be seen in Table 5.

   The probability value in the T-test is smaller than alpha (error level) 0,05 so independent variable benefits of implementation EMS ISO 14001:2015 have strong influences towards dependent variable environmental performance EMS ISO 14001:2015.

2. Statistic F-test

   Statistic F-test is a primary step to identified regression model to decide feasible or not feasible to explain influences between independent variable towards dependent variable. Statistic F test follow F distribution with same criterions with One Way ANOVA. Probability value F count smaller that alpha (error level) 0,05 so regression model is feasible. However, F probability value bigger than alpha (error level) 0,05 so regression model is not feasible. The testing result is explained in Table 6.

   The probability F value in the table is 0,001 smaller than significance level 0,05 so it is explain that regression model is feasible to describe relationship between independent variable benefits

Table 5. T-test of the benefits of implementation EMS ISO 14001:2015

Model	Unstandardized Coeficients		Standardized Coeficient	t	Sig.	95,0% Confidence Interval for B		Correlations		
	B	Std. Error	Beta			Lover Bound	Upper	Zero-order	Partial	Part
1 (Constant)	0,369	0,034		10,923	0,000	0,302	0,436			
Company reputation	0,098	0,098	0,195	3,329	0,001	0,039	0,156	0,283	0,323	0,178
Customer satisfaction	0,143	0,018	0,429	7,801	0,000	0,106	0,179	0,039	0,625	0,417
Employee motivation	0,131	0,018	0,46	7,258	0,000	0,095	0,167	0,616	0,597	0,388
Reduce cost production	0,115	0,018	0,373	6,251	0,000	0,079	0,152	0,587	0,54	0,34

of implementation EMS ISO 14001:2015 that have strong influences towards dependent variable environmental performance EMS ISO 14001:2015. Dewi (2018) explain that independent variable benefits of implementation EMS ISO 14001:2015 have together influences towards dependent variable environmental performance EMS ISO 14001:2015.

Table 6. Result of statistic F-test of benefits of implementation EMS ISO 14001:2015.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1,190	4	0,297	63,566	<,001[b]
	Residual	0,444	95	0,005		
	total	1,634	99			

Classic assumption test

Classic assumption test in this research are as follows:

Normality test

The normality test is residue data formed by the regression model. There are some distribution points near with diagonal line so it was explained that data have normal distribution. The distribution of points in the Normal P-P Plot explains that near with diagonal line so reside data have normal distribution.

Normality test was also conducted using Kolmogorov-Smirnov (Table 7).

Table 7. Results of normality test of the benefits of the implementation EMS ISO 14001:2015.

	N		100
Normal Parameters [a,b]	Mean		0,0000000
	Std. Deviation		0,06700429
Most Extreme Differences	Absolute		0,104
	Positive		0,095
	Negative		-0,104
Test Statistic			0,104
Asymp. Sig. (2-tailed)[c]			0,009
Monte Carlo Sig. (2-tailed)[d]	Sig.		0,008
	99% Confidence Interval	Lower Bound	0,006
		Upper Bound	0,010

According to the normality test, it can be explained that a significance value 0,009 comply normality standard <0,05. Therefore, the dependent variable of benefits EMS ISO 14001:2015 have normal distribution.

The result of the statistical analysis of coefficient regression explains that influences of independent variable benefits of EMS ISO 14001:2015 have strong influences towards dependent variable environmental performance SML ISO 14001:2015 in PT. EPTI. Based on observation and interview to HSE Department personnel, so strong influences contribution of independent variable benefits EMS ISO 14001:2015 towards environmental performance of EMS ISO 14001:2015 caused by:

1. Several employees aware that benefits of implementation EMS ISO 14001:2015. It is explained in the result of questionnaire. There are mostly of employee agree with implementation of EMS ISO 14001:2015 because it can obtain the most important benefits to enhance company reputation. Besides that, employee also aware that other benefits of implementation EMS ISO 14001:2015 are enhancing customer satisfaction, enhancing employee motivation and reducing production cost.

2. PT. EPTI has ISO 14001:2015 certification to prove that they had efforts to manage the environment of the EMS in the company. Environmental performance in this company is 71,35% with middle level. It was described that compliance of standard requirements ISO 14001:2015 supporting with awareness of benefits implementation ISO 14001:2015 that can enhance environmental performance in company.

Contribution of strong influence benefits implementation EMS ISO 14001:2015 towards environmental performance of EMS ISO 14001:2015 based on previous research are:

1. Enhancement of company reputation through EMS implementation has a strong relationship support environmental performance to sustainable company (Rusko et al., 2014). Thus, the benefits of implementation EMS ISO 14001:2015 to enhance environmental performance EMS ISO 14001:2015 and company reputation through EMS implementation is strong relationship to support sustainable development of company.

2. Most of the companies declared that enhancement of customer satisfaction strong influences in environmental performance in sustainable development (Erwin, 2021).

3. Most of the companies declared that enhancement of customer satisfaction strong influences in environmental performance in sustainable development (Khair et al., 2020).

4. Environmental condition support to implement EMS ISO 14001:2015 can enhance employee motivation. Enhancement of employee motivation

can enhance management commitment so the employee will do their exercise optimally and responsibly. Their optimal efforts can support to achieve the company goals and implementation of EMS ISO 14001:2015 (Zulfikar et al., 2019).

Jamaludin (2007) explains that the implementation of EMS ISO 14001:2015 to enhance company reputation and customer satisfaction will decide efforts of product management in market. This aspect depends on trust and customer acceptance, experience and company's knowledge. Khair, et al (2020) explain that enhancement of economic poverty and cost efficiency can achieve by implementation of environment and working environmental integrity that can enhance employee motivation. Company that understands benefits implementation EMS ISO 14001:2015 has 2 (two) reasons in their implementation are reduce natural resources and expand their market or make their new market. Therefore, relationship between EMS ISO 14001:2015 to enhance company reputation, enhance customer satisfaction, enhance employee motivation and reduce production cost have strong influences towards environmental performance EMS ISO 14001:2015 in PT. EPTI can be accept based on previous research had been done.

CONCLUSION

Most of the respondents' perception explained that the benefits of implementation of EMS ISO 14001:2015 are enhancing the company's reputation (93 respondent). The lowest amount of respondent perception describes the benefits of implementation of EMS ISO 14001:2015 are enhancing employee motivation in company (72 respondent).

The benefits of implementation of Environmental Management System (EMS) ISO 14001:2015 have strong relationships with the environmental performance of EMS ISO 14001:2015 which is indicated by regression coefficient 0,717.

Relationship between the benefits of implementation of EMS ISO 14001:2015 in enhancing company reputation, enhancing customer satisfaction, enhancing employee motivation, and reducing production cost have a strong impact on the environmental performance of EMS ISO 14001:2015 in PT. Elang Perdana Tyres Industry (PT. EPTI).

ACKNOWLEDGEMENTS

Thanks to the PT. Elang Perdana Tyres Industry (PT. EPTI) for providing the opportunity, knowledge, and support facilities. I would also like to express my gratitude to the following people: my research mentor as supervisor of HSE Department (Mr. Rosyidin), Production Vice General Manager (Heri Mulyadi), the HSE Manager (Bambang Triawan), R&D Lab Manager (Endang Denok Hadiningrum), and Quality Assurance Manager (Markus) for helpful comments on the initial draft of the paper.

REFERENCES

Abrori, R. F., Oginawati, K. & Sudjono, P. (2018). Analisa kinerja faktor keberhasilan Sistem Manajemen Lingkungan kegiatan industri minyak dengan pendekatan Integrated Environment Performance Measurement System (IEPMS) – AHP (Studi Kasus : PT. Pertamina EP Asset 1 Lirik Field, Riau). *Jurnal Teknik Lingkungan, 24 (1): 81-89*.

Dewi, D. A. N. N. (2018). Modul Uji Validitas dan Reliabilitas. Artikel Ilmiah. Semarang: Universitas Diponegoro.

Erwin (2021). Implementasi sistem ISO 14001 dalam mendukung pencapaian kinerja keberlanjutan perusahaan di Industri Manufaktur Pulp dan Kertas di Indonesia. *Jurnal Vokasi Teknologi Industri, 3(2): 17-24*.

Google. (2023). *Google Earth*. World Wide Web: https://earth.google.com/web/@6.50580147,106.87957503,914.26578373a,13.92220015d,35y,157.14600683h,44.99341923t,0r.373a,13.92220015d,35y,157.14600683h,44.99341923t,0r. Downloaded 28 September 2023.

Haholongan, R. (2016). Kinerja lingkungan dan kinerja ekonomi perusahaan manufaktur *go public*. *Jurnal Ekonomi dan Bisnis, 19(3): 413-423*.

Jamaludin, H. (2007). Tinjauan manfaat dan penerapan ISO 14001 pada beberapa perusahaan. *Jurnal Media Pratama, 3(2): 26-31*.

Kamalia, S., Sari, K. E., & Purnamasari, W. D. (2020). Sistem manajemen lingkungan berdasarkan ISO 14001 di Universitas Brawijaya Malang. *Jurnal Planning for Urban Region and Environment, 9(1): 101-108*.

Khair, N. K. M., Lee, K. E., & Mokhtar, M. (2020). Sustainable city and community empowerment through the implementation of community-based monitoring: A Conceptual Approach. *Sustainability, 12(10): 1-16*.

Kojra, F. R., Sukanta, & Kusnadi. (2020). Analysis of the application of the Environmental Management System based on standards in the international requirements of ISO 14001 . *Journal of Community Based Environmental Engineering and Management, 4(2): 45-50*.

Matondang, Z. (2009). Validitas dan reliabilitas suatu instrumen penelitian. *Jurnal Tabularasa, 6(1): 87-97*.

Monk, K. A. (2020). Promoting interdisciplinary approaches to solving the complexity of environmental problems in Indonesia. *Indonesian Journal of Applied Environmental Studies, 1(2): 1-7*.

Paramita, N. (2009). Pemilihan Konsep Sanitasi Berkelanjutan dalam Peningkatan Fasilitas Limbah Domestik Setempat pada Pemukiman Padat Penduduk Penerima Program Nasional Pemberdayaan Masyarakat (PNPM) Mandiri [Thesis]. Bandung: Program Studi Teknik Lingkungan, Institut Teknik Bandung.

Pratomo, D. S. & Astuti, E. Z. (2015). Analisis Regresi dan Korelasi antara Pengunjung dan Pembeli terhadap Pembelian Nominal di Indomaret Kedungmundu Semarang dengan Metode Kuadrat Terkecil [Karya Ilmiah]. Semarang: Program Studi Informatika. Universitas Dian Nuswantoro.

Priatna, D. & Monk, K. A. (2021). The results of applied research for solutions to environmental problems, expected! Indonesian *Journal of Applied Environmental Studies, 2(1),1-11.*

Ramadan, B. S., Hapsari, S. B., Pramesti, A. L. & Ikhlas, N. (2019). Analisis kuantitatif sistem manajemen lingkungan berdasarkan Klausul ISO 14001 : 2015. *Jurnal Presipitasi, 16(1): 1-7.*

Rusko, M., Sablik. J., Markova, P., Lach, M. & Friedrich, S. (2014). Sustainable development, quality management system and environmental management system in Slovak Republic. *Procedia Engineering, 69(10): 486-491.*

Sari, K. E. & Kamalia, S. (2019). The application of environmental management system based on ISO 14001 in Brawijaya Malang University. *IOP Conf. Series: Earth and Environmental Science, 340(12027): 1-9.*

Utomo, S, W., Sulistyowati, L., Yulianto, G. & Pradafitri, W. S. (2021). *Sistem Manajemen Lingkungan*. Tangerang Selatan: Universitas Terbuka.

Widiyono, W. (2022). DPSIR as an integrated approach to assess natural resources status and development. *Indonesian Journal of Applied Environmental Studies, 3(2): 75-84.*

Zulfikar, R., Sumiyati, S. & Masharyono, M. (2019). Peranan lingkungan kerja dalam menigkatkan motivasi serta dampaknya pada komitmen organisasi karyawan. *Journal of Business Management Education (JBME), 4(2): 24-31.*

InJAST
Volume 4, Number 2, October 2023
Pages: 85-92

P - ISSN: 2722 - 0133
E - ISSN: 2722 - 0141
DOI: 10.33751/injast.v4i2.8976

Analysis of the sustainability status of community-based drinking water supply in Kapongan District, East Java

NUR ANDRIYANTO*, ASEP SUHERI, PRABAWA EKA SOESANTA

Magister Program of Environmental Studies, Open University, Jl. Cabe Raya, Pondok Cabe, Pamulang, South Tangerang 15418, Banten, Indonesia

Corresponding author: *driy.ut21@gmail.com*

Submitted 29 September 2023 ; Accepted 27 November 2023

ABSTRACT

Ensuring the availability and sustainability of clean water is a key focus of the United Nations Sustainable Development Goals (SDGs) and has emerged as a significant concern for both central and local governments in Indonesia. In the Kapongan District of Situbondo Regency, the government's PAMSIMAS Programme is a proactive initiative designed to secure safe access to drinking water for the community. Within this district, two villages, Landangan and Pokaan, have successfully implemented community-based drinking water provision. The ongoing sustainability of these water supply systems in these villages is pivotal for meeting the continuous drinking water needs of the community, necessitating a comprehensive investigation into its sustainability. The primary objective of this study is to assess the sustainability status of community-based drinking water provision within the ongoing PAMSIMAS program in Kapongan District. The dimensions under consideration encompass environmental, social, economic, technological, and institutional aspects. Employing a quantitative approach, the research utilizes the Rap-SPAM analysis method, a modification of Rapfish, with primary data collected through surveys, observations, and interviews. Additionally, secondary data is acquired through an extensive literature review and consultation with various related agencies. The assessment results reveal a sustainability index of 58.92, classifying it as reasonably sustainable. The Multi-Dimensional Scaling (MDS) model produced Stress values ranging from 0.15 to 0.18 and R2 values between 0.93 to 0.94. The variance between the MDS index and Monte Carlo analysis is less than 5%. In conclusion, this study finds that the community-based water supply facilitated by the PAMSIMAS program in Kapongan District demonstrates a reasonably sustainable status. To enhance its sustainability, there is a need to prioritize and improve dimensions with lower sustainability index values in a holistic manner.

ABSTRAK

Memastikan ketersediaan dan keberlanjutan air bersih merupakan fokus utama Tujuan Pembangunan Berkelanjutan (SDGs) PBB dan menjadi perhatian besar bagi pemerintah pusat dan daerah di Indonesia. Di Kecamatan Kapongan Kabupaten Situbondo, Program PAMSIMAS yang dicanangkan pemerintah merupakan inisiatif proaktif yang dirancang untuk menjamin akses yang aman terhadap air minum bagi masyarakat. Di kabupaten ini, Desa Landangan dan Pokaan telah berhasil menerapkan penyediaan air minum berbasis masyarakat. Keberlanjutan sistem pasokan air di desa-desa ini sangat penting untuk memenuhi kebutuhan air minum masyarakat secara berkelanjutan, sehingga memerlukan kajian komprehensif. Tujuan dari penelitian ini untuk menilai status keberlanjutan penyediaan air minum berbasis masyarakat dalam program PAMSIMAS yang sedang berjalan di Kecamatan Kapongan. Dimensi yang dipertimbangkan meliputi aspek lingkungan, sosial, ekonomi, teknologi, dan kelembagaan. Dengan menggunakan pendekatan kuantitatif, penelitian ini menggunakan metode analisis Rap-SPAM, modifikasi dari Rapfish, dengan data primer yang dikumpulkan melalui survei, observasi, dan wawancara. Selain itu, data sekunder diperoleh melalui penelusuran literatur yang ekstensif dan konsultasi dengan berbagai lembaga terkait. Hasil kajian menunjukkan indeks keberlanjutan sebesar 58,92 yang tergolong cukup berkelanjutan. Model Multi-Dimensional Scaling (MDS) menghasilkan nilai Stress yang berkisar antara 0,15 hingga 0,18 dan nilai R2 antara 0,93 hingga 0,94. Perbedaan antara indeks MDS dan analisis Monte Carlo kurang dari 5%. Kesimpulannya, penelitian ini menemukan bahwa pasokan air berbasis masyarakat yang difasilitasi oleh program PAMSIMAS di Kabupaten Kapongan menunjukkan status yang cukup berkelanjutan. Untuk meningkatkan keberlanjutannya, terdapat kebutuhan untuk memprioritaskan dan memperbaiki dimensi dengan nilai indeks keberlanjutan yang lebih rendah secara holistik.

Keywords: *Drinking water supply system, Multi-Dimensional Scaling, PAMSIMAS Programme, Rapfish, sustainability*

INTRODUCTION

Ensuring availability and sustainability of clean water has been targeted in the United Nations Sustainable Development Goals (SDGs) and has become an important issue of both central and local governments in Indonesia (Pambudi, 2023), as climate change has created major social and economic, as well as environmental problems in the country, especially in Sumatra and Java (Monk & Priatna, 2022). Provision of drinking water is a crucial activity to fulfill the needs of a productive, clean, and healthy society, as regulated in Presidential Regulation Number 122 of 2015. The

government strives to achieve 100% access to safe and adequate drinking water, with a target of 15% in the 2020-2024 National Medium-Term Development Plan (RPJMN), in accordance with Presidential Regulation Number 18 of 2020. This initiative aims to improve the quality of life for the community and support sustainable development. The 2005-2025 Medium-Term Regional Development Plan (RPJP) emphasizes the development of adequate drinking water and sanitation facilities as a priority to drive economic growth and overall societal well-being, as stipulated in Law Number 17 of 2007. Additionally, the government has set a target to achieve Sustainable Development Goal (SDG) number 6, which is universal, safe, and affordable access to drinking water by 2030, considering it a fundamental human right and a key promoter of health and well-being, in line with Bappenas (2020) and the United Nations 2015 sustainable development agenda.

In its pursuit of the mission, every ministry has tasks and responsibilities to improve the social, economic, environmental, and cultural well-being of communities, both in the present and for the future (Widiyono, 2020). The PAMSIMAS programme is a government initiative organized by the Ministry of Public Works and Housing (*Kementerian PUPR*) to enhance community access to safe water and proper sanitation (Pamsimas, 2022). The programme focuses on the development of community-based drinking water systems. Government programmes that prioritize empowerment have provided valuable experiences in cost reduction for a given task while maintaining the quality equivalent to non-empowerment programmes (Soesanta, 2013). In its implementation, PAMSIMAS involves community groups in all stages, from planning to maintenance of the water supply systems. The goal is to ensure that communities can access improved drinking water and sanitation (source: https://pamsimas.pu.go.id). The implementation of the PAMSIMAS Programme holds significant importance as a source of raw water to address the current and potential future challenges of clean water scarcity (Suheri et al., 2020).

Situbondo Regency, located in East Java Province, is a target area for the PAMSIMAS programme aimed at improving access to proper drinking water through a community-based approach. As of 2022, a total of 94 villages in Kabupaten Situbondo have benefited from this programme between 2014 and 2022 (DPUPP Kab. Situbondo, 2023). According to Swastomo and Iskandar (2021), the sustainability of water supply in these villages is crucial to ensure the continual fulfillment of the community's drinking water needs. Mukherjee and van Wijk (2003) highlight five interconnected and interdependent aspects in the context of sustainable water and sanitation development: technical, social, financial, environmental, and institutional aspects. The sustainability of water and sanitation development depends on the interaction and support among these five aspects. Therefore, it is essential to conduct a study on the sustainability of the provision of drinking water through the PAMSIMAS programme in functioning villages.

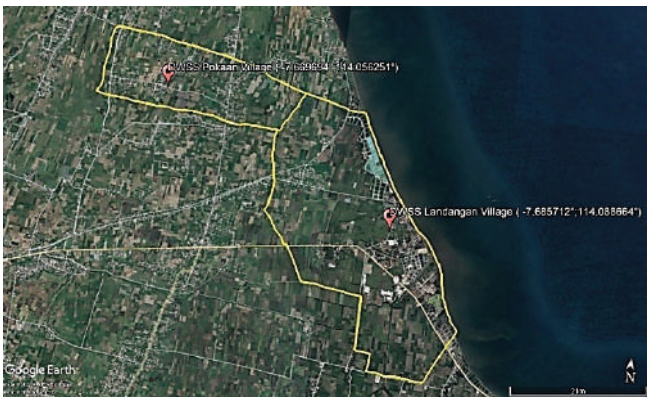
One of the districts in the Situbondo Regency is Kapongan, which has implemented community-involved water supply through the PAMSIMAS programme in five villages within its area. These villages received the programme in the years 2017, 2018, 2021, and 2023. Currently, in Kapongan District, two villages, Landangan and Pokaan, still have functioning drinking water supply systems (DWSS), while in the villages of Peleyan, Seletreng, and Wonokoyo, the systems are non-functional (DPUPP Kab. Situbondo, 2023). This situation has resulted in a lack of access to drinking water for the communities in these villages where the SPAM systems are not functional.

Given this background, research is required to assess the sustainability status of the functioning The Community-based Water Supply Programme (PAMSIMAS). This research aims to ensure the continuity of continuous drinking water access in villages where the DWSS (Drinking Water Supply System) is still operational. Through this study, it is hoped that the sustainability status of the community-based water supply programme under PAMSIMAS can be determined, enabling further improvements and development.

METHODS

Research Location

The research was conducted in the villages of Landangan and Pokaan, Kapongan District, Situbondo Regency, East Java Province. The village of Landangan implemented a community-based water supply system through the PAMSIMAS programme in 2018, managed



(Source: Google Earth, 2023)

Figure 1. Research location at Pokaan and Landangan Villages

by the group named "Samudra Mandiri". On the other hand, the village of Pokaan implemented a community-based water supply system through the PAMSIMAS programme in 2022, managed by the group named "Tirta Jaya". The village locations are depicted in Figure 1.

Materials and Tools

The author directly conducted fieldwork to gather the necessary information, having prepared guidelines to serve as data collection tools. The equipment used for the survey, particularly for interviews, included: questionnaire forms for data collection, writing tools such as pens, pencils, and notepads, and a pocket camera for documentation during the research activities. Data processing was carried out using computer software.

Sampling Method

This research utilized a method of primary data collection through surveys, observations, and interviews with questionnaire completion by relevant respondents. Primary data was obtained directly from users and operators of the Drinking Water Supply System (DWSS). The selection of respondents in each village for DWSS users was done randomly using the simple random sampling technique, meaning the selection of respondents without considering the strata present in the use of drinking water. As for the members of the management group, three members were chosen from the entire DWSS management group, consisting of the chairman, treasurer, and technician. The sample size for drinking water users in each village was determined using the Slovin's formula, as follows (Priyono, 2016):

$$n = \frac{\mathcal{N}}{1 + \mathcal{N}(e)^2}$$

Note:
n= Sample size / number of respondents
$\mathcal{N}$= Population size
e= Percentage of desired sampling error; e=0.1

Based on the formula above, the sample sizes for the PAMSIMAS users in Pokaan village (Tirta Jaya DWSS) and Landangan village (Samudra Mandiri DWSS) were determined to be 50 and 75 respondents, respectively. In addition to primary data, this research also utilized secondary data to support analysis and draw conclusions. Secondary data was obtained through literature reviews from various relevant sources, such as government agencies, universities, textbooks, reports/papers, and other sources relevant to this research.

Research Procedure

This research used the Rap-SPAM method, which is a modification of the Rapfish (Rapid Appraisal for Fisheries) method. The Rapfish method is a statistical technique for the rapid assessment of the relative status of entities (in this case, the fisheries sector), quantitatively assessed against a set of pre-determined attributes grouped into 'evaluation domains' or disciplines (Kavanagh and Pitcher, 2004). Although Rapfish was initially designed for sustainability analysis in the fisheries sector, the fundamental principles of sustainability it developed can be applied to other sectors as well (Fauzi, 2022). The research process with the Rap-SPAM method consists of three main steps: attribute review and sustainability identification, scoring each attribute, and data analysis with Rap-SPAM, as shown in Figure 2.

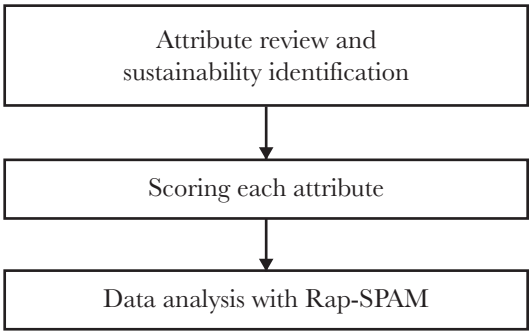


Figure 2. The Rap-SPAM method process.

The first steps, the review of attributes and sustainability identification, involves the determination of attributes based on the five dimensions of sustainability: technical, social, financial, environmental, and institutional. The determination of these attributes is based on various literature studies related to the discussion to assess the sustainability of community-based water supply. The results from the questionnaires and interviews will serve as the fundamental data for the scoring process. The expected attributes that are anticipated to influence the sustainability level of the five reviewed dimensions are presented in Table 1.

Table 1. Determination of dimension attributes.

No	6 Environmental Dimension Attributes
1	Quantity of raw water
2	Protection of water sources
3	Continuity of raw water
4	Pollution potential
5	Surrounding land conditions
6	Rainfall & rainy days
	6 Social Dimension Attributes
7	Practices of using the water supply system
8	Concern for the water supply system
9	Necessity of the water supply system
10	Desire for sustainability

11	Community meetings
12	Community trust
	6 Economic Dimension Attributes
13	Existence of user fees
14	Affordability of user fees
15	Regularity of fee payments
16	Fee adequacy with Operations & Maintenance
17	Existence of fees for the development of the water supply system network
18	Availability of funds for the development of the water supply system
	6 Technological Dimension Attributes
19	Quality of received water
20	Availability of water at all times
21	Ease of technology application
22	Efficiency of water use
23	Quantity of obtained water
24	Network leakages
	6 Institutional Dimension Attributes
25	Regulations for water supply management
26	Clear organizational structure
27	Activity of the management
28	User satisfaction
29	Implementation of rules in water supply system management
30	Performance and financial reporting by the management to the users of the water supply system

The second step is scoring each attribute, which involves converting primary and secondary data obtained into a Likert scale based on the indicators for each attribute that has been prepared. The Likert scale used is 0=poor, 1=moderate, 2=good, 3=very good. The scoring results for each attribute are then analyzed using the Rapfish application, which is an add-in within Microsoft Excel.

The third step is the Rap-SPAM analysis, where the scoring results for each attribute are then analyzed using the Rapfish application, which is an add-in in the MS Excel application. Rap-SPAM ordination is the output of the Rap-SPAM software, depicting the sustainability index. This sustainability index has a range of values between 0-100% and is plotted on two orthogonal axes (x-axis and y-axis). The best scale (good) is reflected by a 100% index value, while the worst scale (bad) is reflected by a 0% index value. Therefore, if the index indicates a value less than 50%, it is categorized as unsustainable. Conversely, if the index shows a value greater than or equal to 50%, it is categorized as sustainable. The description of the resulting ordination index can be provided in four categories of sustainability status, as shown in Table 2.

Table 2. Sustainability criteria.

Index Value	Category	Description
75.01 - 100	Good	Sustainable
50.01 - 75	Fair	Fairluy Sustainable
25.01 - 50	Poor	Less Sustainable
0 - 25	Bad	Not Sustainable

(Source: Yusuf et al. (2021))

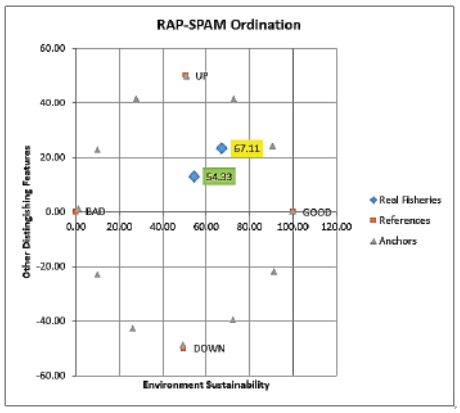
In addition to generating the sustainability index, MDS ordination results along with stress and R^2 values, the automatically scored data is also utilized for Monte Carlo ordination and sensitivity analysis. The Monte Carlo analysis is employed to estimate the influence of errors in the analysis process with a 95% confidence level. Evaluation of stress and coefficient of determination (R^2) values is used to determine whether additional attributes are needed to accurately reflect the evaluated dimensions. According to Kavanagh and Pitcher (2004) as cited in Cocon (2016), a good model is characterized by a stress value below 0.25 and an R^2 value approaching 1, indicating that the MDS analysis is qualitatively reliable.

RESULTS AND DISCUSSIONS

According to the National Urban Water Supply Project (NUWSP, 2020), to support a sustainable and beneficial Community-Based Drinking Water Supply System for the community, there are four important aspects that need attention. The first aspect is the technical-technological aspect, which includes meeting the quality and quantity of drinking water according to standards, as well as ease of application of water technology. The second aspect is the socio-economic cultural aspect, emphasizing the importance of considering the community's ability to subscribe and setting appropriate tariffs. The third aspect is the institutional aspect, which includes a clear organizational structure, regular funding, and attention to operation and maintenance to maintain the sustainability of the system. The fourth aspect is the environmental aspect, which includes strategies to improve the quantity and quality of clean water and environmental capacity to conserve natural resources and the environment. Various factors that directly or indirectly affect the sustainability of water supply are influenced by the participation of the community, institutions, financing, and technical aspects (Krisdhianto and Sembiring, 2016). Moreover, social, environmental, and economic factors also play a significant role in the sustainability of water supply (Djono, 2011).

Sustainability Status of the Environmental Dimension

The analysis using Rap-SPAM on the 6 attributes yielded sustainability index values for the environmental dimension in the community-based drinking water supply system in Landangan Village at 67.11%, categorizing it as moderately sustainable (index falls between 50.01-75.00). Meanwhile, in Pokaan Village, the sustainability index is at 54.33%, also classified as moderately sustainable, as shown in Figure 3.

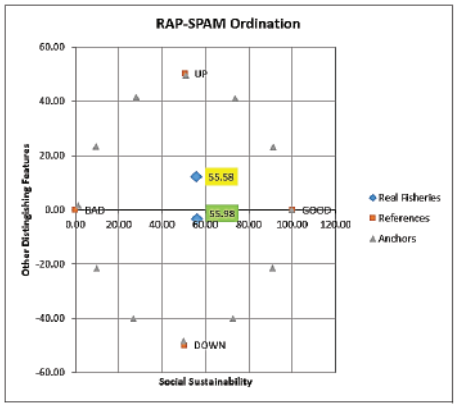


(Source: Analysis, 2023)

Figure 3. Ordination graph of the environmental dimension

Sustainability Status of Social Dimension

The analysis using Rap-SPAM on 6 attributes yielded sustainability index values for the social dimension in the community-based drinking water supply system in the Landangan village of 55.58%, categorizing it as moderately sustainable (index falls between 50.01-75.00). Meanwhile, in the Pokaan village, the index was 55.98%, also classified as moderately sustainable, as shown in Figure 4.

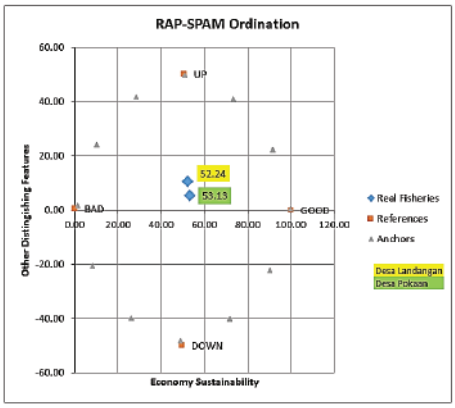


(Source: Analysis, 2023)

Figure 4. Ordination graph of the social dimension

Sustainability Status of Economic Dimension

The analysis using Rap-SPAM on 6 attributes resulted in sustainability index values for the economic dimension in the community-based drinking water supply system Landangan Village at 52.24%, categorizing it as moderately sustainable (index falls between 50.01-75.00). Meanwhile, in the Pokaan village, the sustainability index was 53.13%, also classifying it as moderately sustainable, as shown in Figure 5.

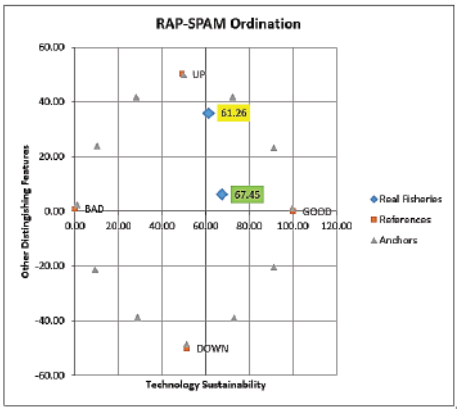


(Source: Analysis, 2023)

Figure 5. Ordination graph of the economic dimension

Sustainability Status of Technology Dimension

The analysis using Rap-SPAM on 6 attributes yielded sustainability index value for the technological dimension in the community-based drinking water supply system in Landangan village of 61.26%, classified as moderately sustainable (the index falls between 50.01-75.00), while in Pokaan village, it was 67.45%, also classified as moderately sustainable, as shown in Figure 6.



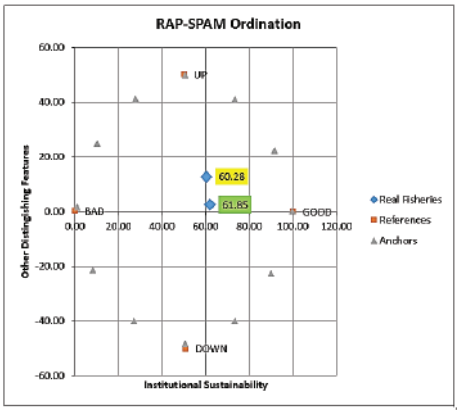
(Source: Analysis, 2023)

Figure 6. Ordination graph of the technological dimension

Sustainability Status of Institutional Dimension

The analysis using Rap-SPAM on the 6 attributes resulted in a sustainability index value for the institutional dimension in the community-based drinking water supply system in the Landangan Village of 60.28%, which falls into the category of fairly sustainable (the index is within the range of 50.01-75.00). Meanwhile, in the Pokaan Village, the sustainability

index is 61.85%, which also falls into the category of fairly sustainable, as shown in Figure 7.



(Source: Analysis, 2023)

Figure 7. Ordination graph of the institutional dimension

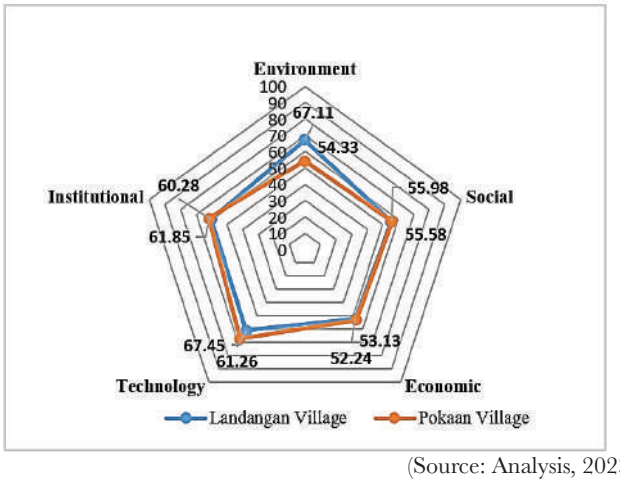
Sustainability Status of Community-Based Drinking Water Supply in Kapongan District

The results of the Rap-SPAM analysis on the five dimensions of community-based drinking water supply in the PAMSIMAS in two villages in the Kapongan District are presented by the sustainability index values and statuses as shown in Table 3 below:

Table 3. Multidimensional Sustainability Index.

Dimension	Index			Status
	DWSS in Landangan Village	DWSS in Pokaan Village	Average	
Environment	67.11	54.33	60.72	Fairly Sustainable
Social	55.58	55.98	55.78	Fairly Sustainable
Economic	52.24	53.13	52.68	Fairly Sustainable
Technology	61.26	67.45	64.35	Fairly Sustainable
Institutional	60.28	61.85	61.07	Fairly Sustainable
Multidimensional	59.29	58.55	**58.92**	**Fairly Sustainable**

(Source: Analysis, 2023)



(Source: Analysis, 2023)

Figure 8. Kite diagram of the sustainability of community-based drinking water supply in Kapongan District.

Overall, the sustainability index score for the community-based drinking water supply programme PAMSIMAS in Kapongan District is 58.92, categorizing it as fairly sustainable. The community-based drinking water supply programme PAMSIMAS in Landangan Village has the highest level of sustainability index with a score of 59.29 (fairly sustainable), while in Pokaan Village, it has the lowest level of sustainability index with a score of 58.55 (fairly sustainable). The sustainability index scores for each dimension are visualized in a kite diagram in Figure 8.

Validity of Analysis Results

The calculation results using the Rap-SPAM approach for all dimensions yielded stress values between 0.15 to 0.18 and R2 values between 0.93 to 0.94, as presented in Table 4. Based on the S and R^2 values, according to the statistical model analysis criteria, a good model is indicated by an S value less than 0.25 and R^2 approaching 1 (Kavanagh and Pitcher, 2004). Therefore, it can be concluded that the model examined in this study is good (good fit) across all dimensions. This demonstrates that all attributes for each dimension have accurately depicted the conditions in the community-based PAMSIMAS programme water supply areas in Kapongan District, making it unnecessary to add or reduce the number of attributes.

Table 4. The Stress and R^2 values for all dimensions.

Parameter	Dimensions				
	Environment	Social	Economic	Technology	Institutional
Stress	0.15	0.17	0.18	0.15	0.17
R^2	0.94	0.93	0.93	0.94	0.94

(Source: Analysis, 2023)

Monte Carlo Analysis in Rap-SPAM is used to examine the influence of errors in the scoring process on attributes due to limitations in information, the variability of scoring due to differences in opinions or assessments of attributes by each respondent, the stability of the MDS ordination process, and errors in data entry (Kavanagh, 2001). Conclusions of the analysis are drawn by comparing the difference between the ordination results in the Monte Carlo sustainability index and the MDS sustainability index, as shown in Table 5 below.

In this study, the Monte Carlo analysis was performed 25 times with a 95% confidence interval, showing that the difference between the MDS index values and the Monte Carlo analysis values was not more than 5%. This indicates that the sustainability index values for each dimension have relatively small random errors (Hardjomidjojo et al., 2016 as cited in Munawir et al., 2022). Therefore, the results of the Monte Carlo analysis support the accuracy of determining the ordination of

the sustainability status of community-based drinking water provision examined.

Table 5. Comparison between MDS index and Monte Carlo.

Dimensions	DWSS Location	Index MDS	Monte Carlo	Deviation
Environment	Landangan Village	67.11	65.53	1.59
	Pokaan Village	54.33	54.17	0.16
Social	Landangan Village	55.58	55.33	0.25
	Pokaan Village	55.98	56.04	0.07
Economic	Landangan Village	52.14	52.24	0.10
	Pokaan Village	53.35	53.13	0.22
Technology	Landangan Village	61.26	60.08	1.18
	Pokaan Village	67.45	66.31	1.14
Institutional	Landangan Village	59.71	60.28	0.57
	Pokaan Village	61.82	61.85	0.04

(Source: Analysis, 2023)

CONCLUSION

From the results of this research, it can be concluded that the status of community-based drinking water provision through the PAMSIMAS programme in Kecamatan Kapongan falls under the category of fairly sustainability with an index value of 58.92. Efforts are needed to improve the sustainability index by prioritizing dimensions with lower sustainability values. Improvements in these sustainability dimensions need to be made holistically. Hence, the involvement and commitment of local government and stakeholders are crucial in enhancing sensitive attributes to support the enhancement of the sustainability index for community-based drinking water provision through the PAMSIMAS programme in Kapongan District.

REFERENCES

Bappenas. (2020). *Metadata Indikator Edisi II, Pilar Pembangunan Lingkungan, Pelaksanaan Pencapaian Tujuan Pembangunan Berkelanjutan/Sustainable Development Goals (TPB/SDGs)*. Jakarta: Badan Perencanaan Pembangunan Nasional.

BPS Kabupaten Situbondo. (2021). *Kecamatan Kapongan dalam Angka 2020*. Situbondo: Badan Pusat Statistik Kabupaten Situbondo.

BPS Kabupaten Situbondo. (2022). *Kecamatan Kapongan dalam Angka 2021*. Situbondo: Badan Pusat Statistik Kabupaten Situbondo.

Cocon. (2016). Analisis Multidimensi Status Keberlanjutan dan Strategi Pengelolaan Kawasan Pengembangan Budidayalaut Berkelanjutan (Studi Kasus di Perairan Teluk Ekas Kabupaten Lombok Timur Provinsi NTB) [Thesis]. Semarang: Program Pascasarjana Universitas Diponegor. Retrieved from http://eprints.undip.ac.id/61413/

Djono, T.P.A. (2011). Analisis Keberlanjutan Sistem Penyediaan Air Minum Pedesaan (Kajian Sistem Penyediaan Air Minum Berbasis Masyarakat di Kabupaten Karanganyar, Provinsi Jawa Tengah sebagai Model Generik Keberlanjutan Sistem Penyediaan Air Minum Pedesaan) [Thesis]. Jakarta: Program Pascasarjana Universitas Indonesia.

Fauzi, A. (2022). *Teknik Analisis Keberlanjutan*. Jakarta: Gramedia Pustaka Utama.

Kavanagh, P. & Pitcher, T.J. (2004). *Implementing Microsoft Excel Software for Rapfish: A Technique for The Rapid Appraisal of Fisheries Status*. Vancouver: The Fisheries Centre, University of British Columbia.

Kavanagh, P. (2001). *RAPFISH Software Description (for Microsoft Excel). Rapid Appraisal for Fisheries (RAPFISH) Project*. Vancouver: Fisheries Center, University of British Columbia.

Krisdhianto, A. & Sembiring, E. (2016). Evaluasi keberlajutan sistem penyediaan air bersih perdesaan di Kecamatan Ledokombo Kabupaten Jember Provinsi Jawa Timur. *Jurnal Teknik Lingkungan, 22 (1): 21-30*.

Mukherjee, N. & van Wijk, C. (2003). *Sustainability Planning and Monitoring in Community Water Supply and Sanitation*. IRC International Water and Sanitation Centre, World Bank.

Munawir, A., Rusdiyanto, E. & Nurhasanah. (2022). *Analisis Statistik Pengelolaan SDA dan Lingkungan Metode Penelitian Aplikasi Software MDS-Rapsettlement*. Tangerang Selatan: Universitas Terbuka.

Monk, K.A. & Priatna, D. (2022). Environmental security and resilience – Indonesia and global challenges. *Indonesian Journal of Applied Environmental Studies, 3 (1): 5-11*. DOI: 10.33751/injast.v3i1.5215

NUWSP. (2020). *Gambaran Umum Sistem Penyediaan Air Minum (SPAM)*. Jakarta: Kementerian Pekerjaan Umum dan Perumahan Rakyat.

Pambudi, A.S. (2023). Evaluation of government funding support for national priority development related to the environmental sector in regions. *Indonesian Journal of Applied Environmental Studies, 4 (1): 10-21*.
DOI: 10.33751/injast.v4i1.7283

Pamsimas. (2022). *Pedoman Umum Pamsimas*. Jakarta: Direktorat Jenderal Cipta Karya, Kementerian Pekerjaan Umum dan Perumahan Rakyat. Retrieved from https://pamsimas.pu.go.id/konten/p-1_pedoman-umum-2022.pdf

Peraturan Pemerintah Republik Indonesia Nomor 122 Tahun 2015 *Tentang Sistem Penyediaan Air Minum* (Lembaran Negara Republik Indonesia Tahun 2015 No. 345)

Peraturan Presiden Republik Indonesia Nomor 18 Tahun 2020 *Tentang Rencana Pembangunan Jangka Menengah Nasional Tahun 2020-2024* (Lembaran Negara Republik Indonesia Tahun 2020, No. 10)

Peraturan Presiden Republik Indonesia Nomor 17 Tahun 2007 *Tentang Rencana Pembangunan Jangka Panjang Nasional Tahun 2005-2025* (Lembaran Negara Republik Indonesia Tahun 2007 No. 33)

Priyono. (2016). *Metode Penelitian Kuantitatif*. Sidoarjo: Zifatama Publishing.

Suheri, A., Kusmana, C., Purwanto, M.Y.J. & Setiawan, Y. (2020). Clean water supply development model in Sentul City. *Jurnal Mimbar, 36 (2): 259-270*.
DOI: https://doi.org/10.29313/mimbar.v36i2.5116

Soesanta, P.E. (2013). Penanggulangan kemiskinan melalui Program Nasional Pemberdayaan Masyarakat (PNPM) Mandiri perdesaan. *Jurnal Bina Praja, 5 (2): 73-78*.
DOI: https://doi.org/10.21787/jbp.05.2013.73-78

Swastomo, A.S. & Iskandar, D.A. (2021). Keberlanjutan sistem penyediaan air minum pedesaan berbasis masyarakat. *Jurnal Litbang Sukowati, 4 (2): 14-27*.
DOI: https://doi.org/10.32630/sukowati.v4i2.131

Widiyono, W. (2020). Natural resources management to deliver Sustainable Development Goals (SDGs). *Indonesian Journal of Applied Environmental Studies, 1 (2): 55-63*.
DOI: https://doi.org/10.33751/injast.v1i2.2188

Yusuf, M., Wijaya, M. Surya, R.A. & Taufik, I. (2021). *MDS-RAPS Teknik Analisis Keberlanjutan*. Makassar: CV. Tohar Media.

InJAST
Volume 4, Number 2, October 2023
Pages: 93-100

P - ISSN: 2722 - 0133
E - ISSN: 2722 - 0141
DOI: 10.33751/injast.v4i2.8957

Relationship between adaptation and mitigation of climate change with the climate village program (ProKlim) In Paser Regency

SYAFRUDDIN ANSHARI*, SRI LISTYARINI, SUBEKTI NURMAWATI

Magister Program of Environmental Studies, Open University, Jl. Cabe Raya, Pondok Cabe, Pamulang, South Tangerang 15418, Banten, Indonesia

Corresponding author: *syafruddinanshari194@gmail.com*

Submitted 26 September 2023 ; Accepted 28 November 2023

ABSTRACT

This study aims to understand the relationship between the Climate Village Program (ProKlim) success rate and climate change adaptation and mitigation actions in Paser Regency. The results of the analysis showed that simultaneously climate change adaptation actions had a real effect on the success rate of ProKlim in Paser Regency by 81.45% with a significance level of 0.00054 (less than α = 0.05), while climate change mitigation actions have a real effect on the success rate of ProKlim in Paser Regency by 83.66% with a significance level of 0.0052 (less than α = 0.05). Meanwhile, the relationship of adaptation actions to the success rate of the ProKlim in Paser Regency is partially influenced by the efforts of control of climate change-related diseases with a significant level of 0.0305 (less than α=0.05). Meanwhile, climate change mitigation actions, it is partially influenced by low-emission agricultural cultivation efforts with a significant level of 0.0305 (less than α=0.05). Thus, the efforts to achieve the success of ProKlim cannot be done partially but must be carried out comprehensively because the impact of climate change has been felt in all aspects so that it is necessary to apply all variables of climate change adaptation and mitigation sustainably.

ABSTRAK

Penelitian ini bertujuan untuk memahami hubungan tingkat keberhasilan Program Desa Iklim (ProKlim) dengan aksi adaptasi dan mitigasi perubahan iklim di Kabupaten Paser. Hasil analisis menunjukkan bahwa secara simultan aksi adaptasi perubahan iklim berpengaruh nyata terhadap tingkat keberhasilan ProKlim di Kabupaten Paser sebesar 81,45% dengan tingkat signifikansi 0,00054 (kurang dari α = 0,05), sedangkan aksi mitigasi perubahan iklim mempunyai pengaruh nyata terhadap keberhasilan ProKlim di Kabupaten Paser. berpengaruh terhadap tingkat keberhasilan ProKlim di Kabupaten Paser sebesar 83,66% dengan tingkat signifikansi 0,0052 (kurang dari α = 0,05). Sedangkan hubungan tindakan adaptasi terhadap tingkat keberhasilan ProKlim di Kabupaten Paser sebagian dipengaruhi oleh upaya pengendalian penyakit terkait perubahan iklim dengan tingkat signifikansi sebesar 0,0305 (kurang dari α=0,05). Sedangkan tindakan mitigasi perubahan iklim, sebagian dipengaruhi oleh upaya budidaya pertanian rendah emisi dengan tingkat signifikan sebesar 0,0305 (kurang dari α=0,05). Dengan demikian, upaya untuk mencapai keberhasilan ProKlim tidak dapat dilakukan secara parsial melainkan harus dilakukan secara komprehensif karena dampak perubahan iklim sudah terasa di seluruh aspek sehingga perlu diterapkannya seluruh variabel adaptasi dan mitigasi perubahan iklim secara berkelanjutan.

Keywords: *adaptation, climate change, climate village, mitigation, Paser regency*

INTRODUCTION

Indonesia is currently faced with tremendous challenges including climate change, biodiversity loss, and broader social and economic change (Monk & Priatna, 2022). Changing climate conditions are currently a phenomenon where the impact has significantly affected various sectors. The changes that can be felt are changes in temperature, weather changes, rainy season patterns and rainfall itself. Although this is a natural occurrence that occurs in the universe, starting in the 1800s, human activities are the main trigger for climate change, especially the use of energy sources derived from fuels such as petroleum, natural gas and coal (Ismiartha et al., 2022).Very significant changes occur in the climate will have a very drastic impact on human life and other living things. The form of impact that arises is in the form of many natural disasters and various kinds of changes related to vital sectors such as food security, safety and health (Ismiartha et al., 2022). Climate change control is one of the sustainable development goals so that environmental issues are targeted by both central and regional governments. Ideally, planning and funding these issues requires top-down and bottom-up harmonization and implementation (Pambudi, 2023). Climate change will cause global warming where the condition of increasing the earth's surface temperature from year to year caused by the impact of greenhouse gases which is a continuation of CO_2, CH_4, NO_2, O_3 and CFC gas emissions which are then trapped in the earth's atmosphere (IPCC, 2007).

The National Climate Village Program (ProKlim) has been running in several regions of Indonesia which is expected to spur policymakers to strengthen capacity in

an effort to deal with climate change through adaptation and mitigation actions tailored to regional conditions (Ismiartha et al., 2022). With the implementation of this program, the government gives appreciation to the community in this case at the level of RWs, hamlets, villages and villages that have actively applied adaptation and mitigation actions in their scope. The level of their ability to carry out adaptation and mitigation actions is divided into four categories, namely Pratama, Madya, Utama and Lestari in accordance with the Regulation of the Director General of Climate Change No P.4 of 2021 concerning Guidelines for the Implementation of the Climate Village Program, where it is explained that if the assessment percentage reaches 50%, it is categorized as ProKlim Pratama, 50% - 81% is included in the Intermediate level, 81% and above as the Main level while the Sustainable category if the ProKlim location has reached the Main level and built several new climate villages. So it is necessary to analyze the factors that can increase the success of the community in the administrative area to be included in the main and Sustainable levels.

Since the launch of the Climate Village Program, Paser Regency, East Kalimantan Province, has had several areas, especially at the village community level, which are registered as Climate Villages in the National Registration System of the Directorate General of Climate Change Control (Ditjen PPI, 2023). The Climate Village Program is a site or local level in question is the most basic location starting from the level of Rukun Masyarakat or Dusun to a slightly higher level, namely Village or Kelurahan to make efforts to raise strength and ability in climate change adaptation and mitigation actions with the intention of being able to improve the welfare of life even though they have to face the phenomenon of climate change (Furqan, 2020).

The previous research explained the partial climate change adaptation and mitigation efforts as conducted by Gebre (2023) which identified the determinants of success of farmers in Kenya in efforts to select climate change adaptation strategies in the food security sector, Rinaldy, et al (2017) by conducting research on community development in building waste banks in an effort to mitigate climate change. Meanwhile, research related to strengthening and developing community institutional capacity in efforts to adapt and climate change was carried out by Dannevig, et al (2022) which produced findings in the form of developing cooperation from various parties in climate change adaptation and mitigation actions, Bohensky et al (2016) revealed that community participation has a role in climate change adaptation and mitigation action efforts as shown by the participation of the community in responding to the top three challenges in identifying problems that arise in climate change. Furthermore, Afni (2021) found that Tobekgadong Village opened up to the Climate Village Program so that it could provide individual understanding in efforts to control climate change. The research to be carried out emphasizes comprehensive climate change adaptation and mitigation action efforts, including institutional strengthening and analyzing strategies for developing climate change control efforts through the Climate Village Program in Paser Regency.

Climate Change Adaptation

Action in an effort to adjust or adapt that has been done by humans due to environmental phenomena that occur is not something new. Countries in regions that have four seasons will adjust to natural conditions according to the seasons that occur. In winter they will use clothes adapted to the conditions of the season at that time. Likewise with the people of Indonesia. Those who live in mountainous areas will use thick clothes to give a warm feeling to the body, while those who live in coastal areas will use thin clothes and easy to absorb sweat because of the hot beach atmosphere. Aldrian et al. (2011) explained that adaptation is defined as an effort to adapt to a changing climate system. So that efforts to reduce the impact or risk of climate change, such as disaster management, are included in climate change adaptation efforts because these actions include efforts to adapt to natural conditions, which experience climate change.

Indonesia is known as an island country so it is very vulnerable to the phenomenon of climate change. In addition, as a developing country, Indonesia's capacity in implementing climate change adaptation actions is not yet on par with developed countries. So it is feared that the implementation of development can be constrained because of this phenomenon. Those who have a very high vulnerability to the impact of climate change are people who are still classified as poor, and also those who feel the most impact from the constraints on the implementation of national development. So that the implementation of climate change adaptation also includes poverty alleviation programs.

Climate Change Mitigation

Without realizing it, most people have taken action to mitigate climate change in various ways, even though it is done without realizing it. For example, some communities that have a penchant for greening various kinds of vegetation, have unwittingly mitigated climate change. Planting trees can provide benefits such as providing shade from the scorching sun, as protection from the wind, lowering the ambient temperature in addition to its benefits which have the ability to absorb greenhouse gas (GHG) emissions. Similarly, those who ride bicycles for transportation, consciously or unconsciously they have implemented climate change mitigation actions. Bicycles are environmentally friendly

vehicles because they do not produce gases from burning fuel into the air, unlike other vehicles that use fossil fuels which have become the largest contributor as a source of greenhouse gas emissions. Based on the description of the examples above, it can be defined that mitigation is various actions or efforts that are actively in preventing climate change or global warming by reducing GHG emissions and / or increasing GHG absorption. It is well known that global warming and climate change are difficult problems to deal with in the future so that mitigation actions are sought to minimize the causes.

In this study, several variables will be used in the Climate Village Program which refers to the National Climate Change Registration System (Ditjen PPI, 2023) as follows:

1. Climate Change Adaptation
   a) Control of droughts, floods and landslides
   b) Improved food security
   c) Control of climate-related diseases

2. Climate Change Mitigation
   a) Waste management, liquid and liquid waste
   b) Use of new renewable energy, conservation and energy saving
   c) Low greenhouse gas emission agricultural cultivation
   d) Improvement or effort to maintain vegetation cover
   e) Forest and land fire prevention and control

3. Institutional Capacity Strengthening
   a) Community institutions
   b) Policy support related to climate change control
   c) Community participation
   d) Community capacity
   e) Support external resources
   f) Development of activities
   g) Action data management

The aim to be achieved in this study is to analyze the relationship between the success rate of climate villages with climate change adaptation and mitigation actions at the site level, in this case climate villages in Paser Regency with a choice of 14 (fourteen) locations. The villages that have received the title as climate villages as well as being used as the basis for problem formulation in analyzing the factors that are used as a basis for improving climate change adaptation and mitigation actions in Paser Regency are as follows:

1. Klempang Sari Village, Kuaro District (Madya)
2. Damit Village, Pasir Belengkong District (Pratama)
3. Padang Pengrapat Village, Tanah Grogot District (Main)
4. Sungai Terik Village, Batu Sopang District (Main)
5. Padang Jaya Village, Kuaro District (Madya)
6. Kertabumi Village, Kuaro District (Madya)
7. Petangis Village, Batu Engau District (Pratama)
8. Modang Village, Kuaro District (Madya)
9. Sebakung Makmur Village, Long Kali District (Madya)
10. Sebakung Taka Village, Long Kali District (Madya)
11. Kendarom Village, Kuaro District (Main)
12. Muser Village, Muara Samu District (Main Thropy)
13. Tajur Village, Long Ikis District (Madya)
14. Laburan Village, Pasir Belengkong District (Madya)

METHODS

Location of Research

The research conducted is quantitative research. Quantitative design is used to analyze activities that have a correlation in determining the success of climate change adaptation and mitigation actions in Paser Regency. The quantitative data comes from locations that have become Climate Villages in the National Registration System of the Directorate of Climate Change Control of the Ministry of Environment and Forestry of the Republic of Indonesia. These adaptation and mitigation action activities are quantified using the Likert scale for each action data obtained. The results of quantitative are then carried out by statistical analysis of multiple regression. Then from the test results, what activities can be applied to illustrate the success rate of the Climate Village Program in Paser Regency.

Data Sources

The determination of data sources for interviewees is carried out purposively, which is chosen with the consideration that only locations that have been registered as Climate Villages under the guidance of the Paser Regency Government but can be applied to other social administrative communities that have not been registered as Climate Villages, especially in Paser Regency if the social conditions have similarities or similarities with the socio-administrative conditions used as research locations. The analysis will be divided into two, namely adaptation actions and climate change mitigation actions. As for climate change adaptation actions, the dependent variable is the success rate of ProKlim with its independent variables, namely: drought, flood and landslide control buildings (X1'1), food security (X1'2), and climate disease control (X1'3). Meanwhile, climate change mitigation actions as dependent variables are the success rate of ProKlim and its independent variables, namely waste and liquid waste management (X2'1), the use of renewable energy, energy conservation and saving (X2'2), low-GHG emission agricultural cultivation (X2'3), increasing and/or

maintaining vegetation cover (X2'4), and preventing and combating forest and land fires (X2'5).

Data Collection

Data collection techniques to be used are interviews, observations and secondary data. For the measurement of each variable parameter independent of adaptation action and climate change mitigation using the Likert system with 4 criteria, namely S = all (100); SB = mostly (67); SK = small part (33); TA = none (0) (Sugiyono, 2013). While the independent variable is based on the ProKlim value of each location listed in the National Registration System of the Directorate of Climate Change Control of the Ministry of Environment and Forestry of the Republic of Indonesia. Data analysis technique is an inferential data analysis technique that is a correlation using multiple regression equations. The regression equation is written as follows:

1. Climate change adaptation action

$$Y = \beta o + \beta 1'1\ X1'1 + \beta 1'2\ X1'2 + \beta 1'3\ X1'3$$

Where:
B1'n = coefficient for variable X1'n
X1'1 = drought, flood and landslide control buildings
X1'2 = food security
X1'3 = climate disease control

2. Climate change mitigation actions

$$Y = \beta o + \beta 2'1\ X2'1 + \beta 2'2\ X2'2 + \beta 2'3\ X2'3 + \beta 2'4\ X2'4 + \beta 2'5\ X2'5$$

Where:
β2'n = coefficient for variable X2'n
X2'1 = waste and liquid waste management
X2'2 = renewable energy use, energy conservation and utilization
X2'3 = low-GHG emission agricultural cultivation
X2'4 = increase and/or maintain vegetation cover
X2'5 = preventing and suppressing forest and/or land fires

RESULTS AND DISCUSSIONS

Taking into account the situation as described above, it is necessary to analyze the relationship between variables of adaptation action and climate change mitigation with the success rate of ProKlim implementation in Paser Regency, East Kalimantan Province.

Climate Change Adaptation Action

By using multiple regression in the excel program, processed data is obtained as follows:

Table 1. Results of multiple regression calculation of climate change adaptation action through ProKlim in Paser Regency.

Regression Statistics	
Multiple R	0.902477529
R Square	0.814465691
Adjusted R Square	0.758805398
Standard Error	7.289755889
Observations	14

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	2332.784027	777.5946755	14.63279564	0.000547131
Residual	10	531.4054092	53.14054092		
Total	13	2864.189436			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	2.3276	14.2394	0.1635	0.8734	-29.3998	34.0550
(X1'1)	0.1736	0.1550	1.1199	0.2889	-0.1718	0.5190
(X1'2)	0.3138	0.1735	1.8086	0.1006	-0.0728	0.7004
(X1'3)	0.3584	0.1424	2.5172	0.0305	0.0412	0.6757

Based on Table 1, the regression equation Y = 2.3276 + 0.1736 X1'1 + 0.3138 X1'2 + 0.3584 X1'3 + e. In this equation, a regression coefficient of 2.3276 is obtained where each independent variable has a positive and unidirectional effect on the dependent variable, which means that the increase in the independent variable.

1) Sign and magnitude calculation

a) Increase in drought, flood and landslide control buildings (X1'1) by 0.1736 where if every one point X1'1 then the success of climate change adaptation will also increase by 0.1736 provided that the value of other independent variables in fixed conditions;

b) Food security (X1'2) of 0.3138 which means that every point X1'2 then the value of food security will increase by 0.3138 provided that the value of other variables is fixed;

c) Control of climate change-related diseases (X1'3) of 0.3584 which means that every point X1'3 then the value of the level of control against climate change-related diseases will increase by 0.3584 provided that the values of other variables are fixed. Meanwhile, the biggest influence on the success of adaptation actions through ProKlim is efforts to control diseases related to climate change.

2) Overall test calculation results (Test F)

Based on Table 1. F calculate is 14.6328 with a significance of 0.000547 (below 0.05) which means that drought, flood and landslide control, food security and climate disease control buildings simultaneously have a real influence on the success of climate change adaptation actions through the Climate Village Program in Paser Regency.

3) Partial test calculation results (Test t)

a) The results of the analysis show that the increase in drought, flood and landslide control buildings has a calculated value of 1.1199 with a significance value of 0.2889. The significance value of 0.2889 is more than 0.05 which can be concluded that the presence of drought, flood and landslide control buildings partially does not have a significant effect on the success of the Climate Village Program.

b) The results of the analysis show that food security has a calculated value of 1.1199 with a significance value of 1.8086. The significance value of 0.1006 is more than 0.05 which can be concluded that food security efforts have no significant effect on the success of the Climate Village Program.

c) The results of the analysis show that control of climate change-related diseases has a calculated value of 2.5172 with a significance value of 0.0305. The significance value of 0.0305 is less than 0.05 which can be concluded that efforts to control climate change-related diseases partially have a significant effect on the success of the Climate Village Program.

4) Coefficient of determination

The regression test results showed that R2 was 0.8145 (81.45%). This shows that 81.45% of the success of climate change adaptation actions through the Climate Village Program can be explained by building variables of drought, flood and landslide control, food security and climate disease control simultaneously while the remaining 18.55% is influenced by other variables that have not been included in the equation.

Climate Change Mitigation Action

By using multiple regression in the excel program, processed data is obtained as follows:

Table 2. Results of multiple regression calculations for climate change mitigation action.

Regression Statistics	
Multiple R	0.914669
R Square	0.836620
Adjusted R Square	0.734507
Standard Error	7.648138
Observations	14

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	2396.2373	479.2475	8.1931	0.0052
Residual	8	467.9522	58.4940		
Total	13	2864.1894			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	11.3362	9.8667	1.1489	0.2838	-11.4165	34.0889
(X2'1)	0.3524	0.2221	1.5869	0.1512	-0.1597	0.8645
(X2'2)	-0.2228	0.1896	-1.1748	0.2739	-0.6600	0.2145
(X2'3)	0.4751	0.1383	3.4097	0.0092	0.1526	0.7904
(X2'4)	0.1883	0.1433	1.3141	0.2252	-0.1422	0.5188
(X2'5)	0.1254	0.1467	0.8547	0.4176	-0.2129	0.4637

Based on Table 2, the regression equation Y = 11.3362 + 0.3524 X2'1 - 0.2228 X2'2 + 0.4715 X2'3 + 0.1883 X2'4 + 0.1254 X2'5 + e. In this equation, a regression coefficient of 11.3362 is obtained where each independent variable has a positive and unidirectional effect on the dependent variable except for the use of renewable energy, conservation and energy harvesting which shows a negative or opposite influence to the success rate of climate change adaptation with ProKlim.

1) Sign and magnitude calculation

a) Waste and liquid waste management (X2'1) of 0.3524 where if every one point X2'1 then the success of climate change mitigation will also increase by 0.3524 provided that the value of other independent variables in fixed conditions;

b) Agricultural cultivation with low GHG emissions (X2'3) of 0.4715 where if every one point X2'3 then the success of climate change mitigation will also increase by 0.4715 provided that the value of other independent variables under fixed conditions;

c) Increase and/or maintain vegetation cover (X2'4) by 0.1883 where if every one point X2'4 then the success of climate change mitigation will also increase by 0.1883 provided that the value of other independent variables under fixed conditions;

d) Prevention and control of forest and/or land fires (X2'5) of 0.1254 where if every one point X2'5 then the success of climate change mitigation will also increase by 0.1254 provided that the value of other independent variables in fixed conditions. Meanwhile, the biggest influence on the success of mitigation actions through ProKlim is low-GHG emission agricultural cultivation.

2) Overall test calculation results (Test F)

Based on Table 2. F calculate obtained 8.1931 with a significance of 0.0052 (below 0.05) which means that waste and liquid waste management, the use of renewable energy, conservation and energy saving, agricultural cultivation are low GHG emissions, increasing and/or maintaining vegetation cover, preventing and combating forest and/or land fires simultaneously have a significant influence on the success of climate change mitigation actions through the Climate Village Program in Paser Regency.

3) Partial test calculation results (Test t)

a) The results of the analysis show that waste and liquid waste management has a calculated value of 1.5869 with a significance value of 0.1512. The significance value of 0.1512 is more than 0.05 which can be concluded that partial waste and liquid waste management does not have a significant effect on the success of mitigation actions for the Climate Village Program in Paser Regency.

b) The results of the analysis showed that the use of renewable energy, conservation and energy saving was calculated at -1.1748 with a significance value of 0.2739. The significance value of 0.2739 is more than 0.05 which can be concluded that partially the use of renewable energy, energy conservation and saving does not have a significant effect on the success of mitigation actions of the Climate Village Program in Paser Regency.

c) The results of the analysis showed that low-emission agricultural cultivation was calculated at -3.4097 with a significance value of 0.0092. The significance value of 0.0092 is less than 0.05 which can be concluded that partially low-emission agricultural cultivation has a significant effect on the success of mitigation actions of the Climate Village Program in Paser Regency.

d) The results of the analysis show that increasing and/or maintaining vegetation cover has a calculated value of 1.3141 with a significance value of 0.2252. The significance value of 0.2252 is more than 0.05 which can be concluded that partially increasing and/or maintaining vegetation cover does not significantly affect the success of mitigation actions of the Climate Village Program in Paser Regency.

e) The results of the analysis show that efforts to prevent and overcome forest and/or land fires have a calculated value of 0.8547 with a significance value of 0.4176. The significance value of 0.2252 is more than 0.05 which can be concluded that partially increasing and/or maintaining vegetation cover does not significantly affect the success of mitigation actions of the Climate Village Program in Paser Regency.

4) Coefficient of determination

The regression test results showed that R2 was 0.8366 (83.66%). This shows that 83.66% of the success of climate change mitigation actions through the Climate Village Program in Paser Regency can be explained by waste and liquid waste management efforts, the use of renewable energy, energy conservation and saving, Low-emission agricultural cultivation, increasing and/or maintaining vegetation cover, efforts to prevent and control forest and/or land fires, simultaneously while the remaining 16.34% is influenced by other variables that have not been included in the equation.

CONCLUSION

Based on the results of research and discussion, the following can be concluded:

1. There is a positive and significant relationship between the level of the ProKlim in Paser Regency and climate change adaptation actions in the form of efforts to develop drought, flood and landslide control, food security efforts and climate disease control efforts simultaneously, which is shown by an R2 value of 0.8145 which means that the variable of climate change adaptation action has a real effect on the success rate of ProKlim in Paser Regency by 81.45% with a significance of 0.00054 (less than α = 0.05), while the remaining 18.55 is influenced by other factors that are not contained in the equation model.

2. The relationship between the success rate of climate change adaptation actions through ProKlim in Paser Regency and with partial climate change adaptation efforts is marked by a partial significance value, namely the increase in drought, flood and landslide control buildings has a significance value of 0.2889 (greater than α = 0.05); food security efforts with a significance value of 1.8086 (more than α = 0.05); while control of climate change-related diseases has an influence on the success of ProKlim which is indicated by a significance value of 0.0305 (less than α = 0.05).

3. There is a positive and significant relationship between the success rate of the ProKlim in Paser Regency and climate change mitigation actions in the form of waste and liquid waste management efforts; use of renewable energy; energy conservation and saving; low-emission agricultural cultivation; increase and/or maintain vegetation cover; efforts to prevent and forest and/or land fire management; simultaneously, which is shown by an R2 value of 0.8366 which means that the variable of climate change mitigation action has a real effect on the success rate of ProKlim in Paser Regency by 83.66% with a significance of 0.0052 (less than α = 0.05), while the remaining 18.55 is influenced by other factors that are not contained in the equation model.

4. The relationship between the success rate of climate change mitigation actions through ProKlim in Paser Regency and partial climate change mitigation efforts shows that waste and liquid waste management has a significance value of 0.1512 (more than α=0.05); the use of renewable energy, conservation and saving has a significance of 0.2739 (more than α=0.05); low-emission agricultural cultivation significance value of 0.0092 (less than α=0.05); increasing and/or maintaining vegetation cover has a significance value of 0.2252 (more than α=0.05); Efforts to prevent and overcome forest and/or land fires have a significance of 0.4176 ((more than α=0.05).

ACKNOWLEDGEMENTS

Thanks to the Environmental Agency of Paser, as well as to all Head of Climate Villages for providing the opportunity, knowledge, and facility support in this research. I would also like to express my gratitude to the following parties: Supervisor of PT. Pama Persada Nusantara Batu Kajang Site, Mr. Winardi (Lecturer of Muhammadiyah Kalimantan University), Fifi (Planet Urgence), as well as Andi Rahayau and Rina Ratnasari (Functional staff of Environmental Agency of Paser Regency.

REFERENCES

Afni, Z., Sari, F.M. & Prihati. (2021). Penguatan Kelembagaan Kampung Iklim Tobekgedong Kota Pekanbaru Terhadap Kebijakan Perubahan Iklim. *Jurnal Masyarakat Mandiri, 5(4),1597-1605*, Retrieved from https://journal.ummat.ac.id/index.php/jmm/article/download/5074/2973

Aldrian, E., Karmini, M., & Budiman. (2011). *Adaptasi dan Mitigasi Perubahan Iklim di Indonesia*, Pusat Perubahan Iklim dan Kualitas Udara Kedeputian Bidang Klimatologi Badan Meteorologi, Klimatologi dan Geofisika (BMKG).

Bohensky, E.L., Kirono, D.G.C., Butler, J.R.A., Rochester, W., Habibi, P., Handayani, T., & Yanuartati, Y. (2016). Climate knowledge cultures: Stakeholder perspectives on change and adaptation in Nusa Tenggara Barat, Indonesia, *Climate Risk Management 12*. Retrieved from http://dx.doi.org/10.1016/j.crm.2015.-11.004

Dannevig, H., Korsbrekke, M.H., & Hovelsrud, G.K. (2022). Advancements of sustainable development goals in co-production for climate change adaptation research, *Climate Risk Management, 36, 1-9*, Retrieved from https://doi.org/10.1016/j.crm.2022.100438

Direktorat Jenderal Pengendalian Perubahan Iklim (Ditjen PPI). (2023). Sistem Registrasi Nasional, Retrieved from https://srn.menlhk.go.id/index.php?r=-aksi%2Fview&id=12379

Furqan, M.H., Azis, D., & Wahyuni, R. (2020). Implementasi Program Kampung Iklim (ProKLim) di Gampong Lambung Kecamatan Meuraxa Kota Banda Aceh, *Jurnal Pendidikan Geosfer, V(2), 42-49*. Retrieved from https://jurnal.usk.ac.id/JPG/article/-view/21691/14231

Gebre, G.G., Amekawa, Y., Fikadu, A.A., & Rahut, D.B. (2023). Farmers' use of climate change adaptation strategies and their impacts on food security in Kenya, *Climate Risk Managemeny, 40,1-14*, Retrieved from https://doi.org/10.1016/j.crm.2023.100495

Ismiartha, G.R., R.S., Santoso, R.S., & Hanani, R. (2022). Analisis Stakeholders dalam Kegiatan Pengelolaan Sampah Program Kampung Iklim (Proklim) sebagai Upaya Mitigasi Perubahan Iklim Dusun Soka, Desa Lerep, Kecamatan Ungaran Barat, Kabupaten Semarang. *Journal of Public Policy and Management Review. 10 (2):1-18*, Retrieved from https://doi.org/-10.14710/jppmr.v10i2.-30591

IPCC. (2007). Climate Change 2007 : The Physical Science Basis : Summary for Policymakers, *4th Assessment Report, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, Retrieved from https://www.ipcc.ch/report/ar4/wg1

Monk, K.A. & Priatna, D. (2022). Environmental security and resilience Indonesia and global challenges, *Indonesian Journal of Applied Environmental Studies. 3(1),5-11*, Retrieved from http://dx.doi.org/10.33751/-injast.v3i1.5215

Pambudi, A.S. (2023). Evaluation of government funding support for national priority development related to environmental sector in regions. *Indonesian Journal of Applied Environmental Studies. 4(1),10-21*, Retrieved from http://dx.doi.org/10.33751/injast.v4i1.7283.

Sugiyono. (2013). *Metode Penelitian Kuantitatif Kualitatif dan R&D*, Bandung: Alfabeta Bandung Edisi ke 19.

InJAST
Volume 4, Number 2, October 2023
Pages: 101-106

P - ISSN: 2722 - 0133
E - ISSN: 2722 - 0141
DOI: 10.33751/injast.v4i2.8966

Application of potassium fertilizer and plant growth regulators to the growth and productivity of purple sweet potato

DESTY DWI SULISTYOWATI[1,*], WAHYU WIDIYONO[2]

[1]Research Centre for Plant Conservation, Botanical Garden, and Forestry, The National Research and Innovation Agency, Soekarno Science and Technology Area, Jl. Raya Jakarta Bogor km. 46 Cibinong Bogor 16911, Indonesia

[2]Research Centre for Environmental and Clean Technology, The National Research and Innovation Agency, Samaun Samadikun Science and Technology Area, Jl. Cisitu Lama, Jl. Sangkuriang, Dago, Coblong, Bandung 40135, Indonesia

Corresponding author: *dest003@brin.go.id*

Submitted 27 September 2023 ; Accepted 28 November 2023

ABSTRACT

The study aimed to determine the effect of plant growth regulators and potassium fertilizer on the growth and productivity of three clones of purple sweet potato. The experiment was conducted at IPB University experimental station in Leuwikopo Dramaga Bogor for seven months. The study used a split-plot design with three factors and three replications. The first factor was as a subplot, namely plant growth regulators (PGR) application which consisted of two levels of without PGR (S0) and with PGR (S1) concentration of 2 cc l^{-1} of water (2,000 ppm). The second factor was as a subplot, namely rates of potassium chloride fertilizer (60, 120, 180 kg ha^{-1} K_2O). The third factor as the main plot was sweet potato clones of (K1) Ayamurasaki, (K2) RIS-03063-05, and (K3) MSU 03028-10. The concentration of 2,000 ppm PGR did not significantly affect growth and tuber yield components. Potassium chloride K_2O of 60 kg ha^{-1} up to 180 kg ha^{-1} did not significantly affect growth and tuber yield components. MSU 03028-10 clone had the highest total tuber yield (1537.8), healthy tuber (1529.9), unmarketable tuber (740.3), and small tuber (709.0). MSU 03028-10 clones have the longest stem length and the largest number of leaves 3-12 WAP. This study indicates that the MSU 03028-10 clone produces better growth and productivity than other clones.

ABSTRAK

Penelitian bertujuan untuk mengetahui pengaruh zat pengatur tumbuh dan pupuk kalium terhadap pertumbuhan dan produktivitas tiga klon ubi jalar ungu. Percobaan dilakukan di Kebun Percobaan IPB University di Leuwikopo Dramaga Bogor selama tujuh bulan. Penelitian menggunakan rancangan petak terbagi (*split-plot design*) dengan tiga faktor dan tiga ulangan. Faktor pertama sebagai anak petak yaitu pemberian zat pengatur tumbuh (PGR) yang terdiri dari dua taraf yaitu tanpa PGR (S0) dan dengan PGR (S1) konsentrasi 2 cc l^{-1} air (2.000 ppm). Faktor kedua sebagai anak petak yaitu takaran pupuk kalium klorida (60, 120, 180 kg ha^{-1} K_2O). Faktor ketiga sebagai petak utama adalah klon ubi jalar (K1) Ayamurasaki, (K2) RIS-03063-05, dan (K3) MSU 03028-10. Konsentrasi PGR 2.000 ppm tidak berpengaruh nyata terhadap komponen pertumbuhan dan hasil umbi. Kalium klorida K_2O ukuran 60 kg ha^{-1} sampai dengan 180 kg ha^{-1} tidak berpengaruh nyata terhadap komponen pertumbuhan dan hasil umbi. Klon MSU 03028-10 mempunyai hasil total umbi tertinggi (1537,8), umbi sehat (1529,9), umbi tidak layak jual (740,3), dan umbi kecil (709,0). Klon MSU 03028-10 mempunyai panjang batang terpanjang dan jumlah daun terbanyak 3-12 MST. Penelitian ini menunjukkan bahwa klon MSU 03028-10 menghasilkan pertumbuhan dan produktivitas yang lebih baik dibandingkan klon lainnya.

Keywords: *clone, sweet potato, vegetative*

INTRODUCTION

Indonesia has local sweet potato resources in several parts of Indonesia as a source of biodiversity. In Indonesia, sweet potatoes have spread almost to various parts of Indonesia. Some of Indonesia's local sweet potatoes include Cilembu sweet potatoes from the Cilembu region of West Java, Goroho sweet potatoes from the Gorontalo area, Jeneponto sweet potatoes from the South Sulawesi region, as well as Helaleke, Yeleli, and Musaneken sweet potatoes which are local sweet potatoes from Papua.

Sweet potato is a source of carbohydrates that are used as food. The current direction of sweet potato utilization is its function (functional food) as a health food (Ginting et al., 2011; Saputro et al., 2023). Besides being a food ingredient, it also has an important role in health. Anthocyanins in sweet potatoes have various useful functions for the body such as anti-oxidants, anti-hypertension, prevention of disorders, and liver function Jusuf (2011).

The increasing demand for anthocyanin-rich sweet potatoes as raw materials for the food industry causes the need to increase purple sweet potato yields. Ayamurasaki is a purple sweet potato clone introduced from Japan that has been cultivated in Indonesia. Apart from Ayamurasaki, there are new superior clones that have

anthocyanin content and higher yield potential than Ayamurasaki, namely RIS 03063-05 and MSU 03028-10.

Cytokinin is a Plant Growth Regulator (PGR) that plays a role in stimulating plant growth. The main function of cytokinin is to stimulate cell division and promote cell enlargement. Bradshaw et al. (2009) stated that cytokinin levels rose sharply just before the initiation of sweet potato. The levels of these cytokinin remained high until the sweet potatoes were nearing maturity, then decreased. Cytokinin stimulate the formation of sweet potatoes by inhibiting starch hydrolysis activity and stimulating starch synthesis activity. Cytokinin is generally used for stem growth, while auxins are used for root growth. However, both are often needed depending on the ratio of cytokinin to auxin or vice versa (Lestari 2011).

The translocation of carbohydrates from shoots to roots Nedunchezhiyan et al. (2012). This experiment aims to study the effect of growth regulators and potassium fertilizer on the productivity of three purple sweet potato clones. The results of this study are expected to increase the productivity of purple sweet potatoes with the use of superior clones, potassium fertilizer and appropriate PGR substances.

METHODS

The experiment was carried out in the experimental garden of IPB at Leuwikopo, Dramaga, Bogor, at an elevation of 250 m above sea level (asl). The experiment was carried out for seven months from September 2013 to March 2014. The seeds used in this experiment were purple sweet potato cuttings from three clones, namely Ayamurasaki, RIS 03063-05, and MSU 03028-10. Fertilizer given were 100 kg of urea ha^{-1}, 100 kg of SP-36 ha-1, and KCl with doses according to the treatment, namely 100, 200, and 300 kg ha^{-1}. Hormax growth regulator containing auxin IAA 108.56 ppm, auxin IBA 83.72 ppm, cytokinin kinetin 98.34 ppm, cytokinin zeatin 107.81 ppm, ABA 89.35 ppm, GA3 118.40 ppm, ethylene 168 ppm, traumatic acid 212 ppm, ethylene 168 ppm , and humic acids 354 ppm. The tools used are plant cultivation equipment, hand counters, hand sprayers, meters, digital scales, and ovens.

using three factors and three replications. The first factor that became the children of the plots was the administration of growth regulator (S) consisting of two levels, namely no treatment and a concentration of 2,000-2,000 ppm. The second factor as a subplot was the application of KCl (P) fertilizer consisting of three levels, namely: 100 kg ha-1 (K2O equivalent 60 kg ha^{-1}), 200 kg ha^{-1} (K_2O equivalent 120 kg ha^{-1}), and 300 kg ha^{-1} (K_2O equivalent of 180 kg ha^{-1}). The third factor as the main plot were two sweet potato clones (K), namely: Ayamurasaki clone, RIS 03063-05, and MSU clone 03028-10. Variables observed included vegetative variables and tuber yield component variables. Vegetative variables include stem length, number of leaves, and number of branches.

The components of tuber yield include total tuber weight, healthy tuber weight, tuber weight attacked by plant pests, salable tuber weight, unsalable tuber weight, and small tuber weight. Data analysis using variance. If the results of the variance show a significant effect at the P level <0.05, then it is continued with the Duncan multiple range test (DMRT).

RESULT AND DISCUSSION

The experimental results showed that all the variable components of tuber yield were different between clones. The clones had differences in the vegetative variables of stem length, except 12 WAP and in the number of leaves, except 3 WAP. Variable number of branches did not differ between clones. The treatment factors of potassium fertilization, administration of growth regulators and the interaction of two and three treatment factors did not show a significant effect on all vegetative variables or tuber yield variables.

Effect of PGR Application on Vegetative Growth and Tubers Yield Components

PGR application did not significantly affect sweet potato vegetative growth (Table 1). High rainfall is one of the factors that affect the effectiveness of PGR. Rainfall at the time of PGR application was high [503 mm on average in September 2013 (4 MST), 394 mm in October 2013 (8 MST) and 187 mm in November 2013 (12 MST)].

Table 1. Effect of PGR application on stem length, number of leaves, and number of branches.

PGR	Age (WAP)			
ppm	3	6	9	12
	Stem length (cm)			
0	112.2	145.2	185	259.6
2000	107.9	138.4	184.5	261.2
	Number of leaves (strands)			
0	49.1	104	173.7	227.1
2000	49.3	104.6	165.2	227.4
	Number of branches			
0	5.7	9.4	10.3	11.8
2000	5.4	8.7	10.2	12.3

According to Schmidt and Ferguson's climate classification, months with rainfall > 100 mm are included in the wet months (Assyakur, 2009). The high rainfall facilitates the leaching of growth regulators that have been applied to the surface of the sweet potato plant canopy to be wasted because they are not absorbed

by plants, lost through evaporation, due to washing, or carried away by rainwater (run off). Krisantini (2011) explained that the things that affect the effectiveness of growth regulators to get the desired effect, when applying PGR, attention must be paid to the type of plant and its growth phase, the type of PGR used, the weather conditions and the growing environment, as well as the technical culture of the plants in the field.

Table 2 shows that the percentage of tubers attacked by pests that were treated with PGR 2,000 ppm was lower than the control treatment. Healthy tubers were induced more in PGR-treated plants compared to controls. The condition of the plants that were given PGR resulted in the induction of flavonoids as raw material for anthocyanins in tubers.

Table 2. Effect of giving PGR on tuber yield components.

Tuber yields	0 ppm		2000 ppm	
	(g $(7m^2)^{-1}$)	%[b]	(g $(7m^2)^{-1}$)	%[b]
Total tubers	999.6		1116.4	
Healthy tubers	985	96.2	1097.5	99.6
Tubers attacked by pest	14.4	3.7	33.8	0.4
Tubers fit for tubers	552	52.5	588.1	46.7
Tubers not fit for sale	447.3	47.4	542.9	53.3
Small tubers	432.9	43.7	509.2	52.9

Note: Total tuber is the total tuber weight; Healthy tubers are tubers worth selling and small tubers that are free from pest attack; Tubers fit for sale are healthy tubers measuring > 100 g; Tubers unfit for sale are bulbs attacked by pest and small tubers; Small tubers are tubers weighing < 100 g; b Percentage to total tubers.

The anthocyanins that are formed make the purple sweet potato's defense against pest attacks stronger and the plants healthier. Anthocyanins are secondary metabolites of the flavonoid group. Anthocyanin is a chemical substance that functions directly as a repellent and indirectly as a visual signal. Anthocyanins also function as anti-inflammatory and anti-candida (Sucharat et al., 2016). This is reinforced by the statement of Werlein et al. (2005) that anthocyanins can protect plants from infections caused by pathogenic microorganisms. The antimicrobial activity of anthocyanins is slightly more effective than other phenolic compounds such as hydroxycinnamic acids which can also be produced in the roots (Werlein et al., 2005).

The Effect of Potassium Application on Vegetative Growth and Tubers Yield Components

Based on Table 3, the application of potassium fertilizer has no significant effect on the growth of sweet potatoes. Vegetative growth that occurred in this experiment is thought to be more influenced by the factor of water availability through high rainfall.

Table 3. Effect of potassium fertilization on stem length, number of leaves, and number of branches.

Fertilizer dosage (kg ha^{-1})	Age (WAP)			
	3	6	9	12
	Stem length (cm)			
60	114.7	143.2	185.1	252.9
120	111.1	145	190.9	266.5
180	104.4	137.2	178.3	261.8
	Number of leaves (strands)			
60	53.9	98.7	151.9	226.8
120	45.9	118.6	182.3	228.5
180	47.8	95.7	174.2	226.4
	Number of branches			
60	5.8	7.9	10.2	11.8
120	5.2	9.9	10.5	11.9
180	5.7	9.3	10	12.4

The nitrogen content remained low (0.18%) at the beginning and at the end of planting after fertilization. This is because the nitrogen provided is used by plants and some of it is washed away by rainwater. Rainfall also has an impact on nitrogen levels in the soil which causes the growth of the sweet potato plant canopy to become larger. This assumption is reinforced by Rasyid's statement (2010) that the interaction treatment of water and nitrogen fertilizers on corn plants gave a significant increase in corn plant growth (plant height, cob weight, chestnut weight, total plant dry weight, N content, and N uptake).

Potassium fertilization has not significantly increased tuber yield (Table 4). This is presumably because the dose given is still not pestimal to increase tuber yield. Research on potassium fertilization in Kenya showed that the highest weight of potato tubers of the Ajiba variety was 1.14 kg per plant and the productivity was 49.38 tons ha^{-1} with the addition of 300 kg K_2O ha^{-1} (Zelelew & Ghebreslassie, 2016). Potassium K_2O given in the experiment was still lower with a dose of 60 kg ha^{-1} to 180 kg ha^{-1}. Sweet potato yield will increase proportionally with increasing available potassium that can be absorbed by plants. This is related to the function of the element potassium, which is to transport photosynthate from source to sink. This is reinforced by the statement of Pahlevi et al. (2016) that potassium plays an important role in the tuber enlargement process because of its participation in the assimilation translocation process from the source to the tuber storage.

Table 4. The effect of potassium fertilizer doses on tuber yield components.

Tubers yield ($g\ (7m^2)^{-1}$)	60 kg ha^{-1}	%[b]	120 kg ha^{-1}	%[b]	180 kg ha^{-1}	%[b]
Total tubers	843,1		1122,4		1208,6	
Healthy tubers	839,4	99,6	1079,7	96,2	1204,6	99,7
Tubers attacked by pest	3,6	0,4	41,2	3,7	27,6	2,3
Tubers fit for tubers	393,6	46,7	588,8	52,5	727,8	60,2
Tubers not fit for sale	449,4	53,3	531,7	47,4	504,3	41,7
Small tubers	445,8	52,9	490,5	43,7	476,8	39,5

Potassium fertilizers may have been leached by high rainfall of 503 mm in September 2013 at 1 MST fertilizer application and 394 mm in October 2013 at 6 MST fertilizer application. This causes the availability of K_2O content in the soil to decrease. Potassium was available in the soil although its value increased from 0.23 me 100 g^{-1} before treatment to 0.77 me 100 g^{-1} after treatment. However, the addition of potassium does not increase the yield component of the tuber because the roots are less able to absorb potassium in the soil. This is thought to be due to excess water in the soil. High rainfall causes too much crown growth, causing competition between the crown and tubers as a sink. This is confirmed by the experiment of Wandana et al. (2012) regarding the application of potassium fertilizer to sweet potato plants which did not significantly affect tuber weight due to environmental influences in the form of high rainfall during application, namely 204.1 mm in March and 144.2 mm in April 2012. Effect of high rainfall on tuber yield related to the low number of tubers, namely inhibition of tuber initiation. The decrease in weight per tuber is thought to be due to the lack of assimilate translocated to the tubers and the slow activity of the primary cambium. The size of tubers in the field is basically greatly influenced by the first 20 days after planting. Suwarto et al. (2006) explained that the period between root formation at 4 WAP and the beginning of tuber formation at 8 WAP will increase the capacity of sweet potato plants to absorb nutrients in the root area.

Vegetative Growth and Yield Components of Various Clone

Clone RIS 03063-05 showed low adaptability at the start of planting (1 WAP) (Table 5), and based on Table 6 clone RIS 03063-05 had the lowest yield component in the field. In the first week of planting, it rarely rains, so every day watering is done to the seeds that have been planted. Several cuttings of clone RIS 03063-05 died due to drought even though they had been watered for the first week after planting. Most of the surviving cuttings experience drying of the leaves to the point where they first defoliate and then form new leaves. Seeds that experienced death were embroidered in the first and second weeks. In the second week it rains more frequently so that the soil is sufficiently moist and plant growth is evenly distributed.

Table 5. Stem length, number of leaves, and number of branches of various clones.

Clone	Age (WAP)			
	3	6	9	12
	Stem length (cm)[a]			
Ayamurasaki	91.8a	122.2b	172.1b	237.6
RIS 03063-05	80.2b	113.6b	156.0b	231.3
MSU 03028-10	158.2a	189.7a	226.1a	312.3
	Number of leaves (strands)[a]			
Ayamurasaki	51.7	74.9b	125.7b	180.7b
RIS 03063-05	50.7	76.0b	143.5b	194.8b
MSU 03028-10	51.7	162.1a	239.1a	306.2a
	Number of branches			
Ayamurasaki	6.2	9.9	10.9	12.4
RIS 03063-05	5.9	9.4	10.8	12.3
MSU 03028-10	4.6	7.9	9	11.4

Note: a: Numbers followed by the same letter on the same line are not significantly different on the 5% DMRT follow-up trial.

The Ayamurasaki clone had good adaptability at the start of growth (1 WAP) and had the largest number of salable cassava (Table 6). At the beginning of 1 MST growth, the Ayamurasaki and MSU 03028-10 clones did not drop their leaves first, continued to grow and form new leaves. Early growth of MSU 03028-10 clone showed good adaptation and faster stem elongation than the other two clones. This can be seen in the third week, clone MSU 03028-10 had the longest stem, and so did the following weeks (Table 5). MSU clone 03028-10 had the highest number of total tubers and healthy tubers of the other two clones (Table 6). The yield value of salable tubers of the MSU 03028-10 clone was not significantly different from that of the Ayamurasaki clone. However, if the desired consumer preference is for coloring in the food industry, the MSU 03028-10 clone (590.8 mg 100 g^{-1} BB) is more profitable to develop because it has a higher anthocyanin content than the Ayamurasaki clone (281.90 mg 100 g^{-1} BB). . Anthocyanin pigments are natural dyes that cause red, orange, purple and blue colors. Anthocyanin pigments are mostly found in flower

Table 6. Components of tuber yields of various clones.

Tubers yield	(g $(7m^2)^{-1}$)[a] (ayamurasaki)	%[b]	(g $(7m^2)^{-1}$)[a] (RIS 03063-05)	%[b]	(g $(7m^2)^{-1}$)[a] (MSU 03028-10)	%[b]
Total tubers	1531,7a		104,6b		1537,8a	
Healthy tubers	1489,0a	97,2	104,6b	100	1529,9a	99,5
Tubers attacked by pest	41,1a	2,9	0,0b	0	31,3ab	2,0
Tubers fit for tubers	872,4a	57	17,2b	16,4	820,6a	53,4
Tubers not fit for sale	657,7a	42,9	87,4b	83,6	740,3a	46,1
Small tubers	616,6a	40,3	87,4b	83,6	709,0a	46,1

Note: Total tuber is the total tuber weight; Healthy tubers are tubers worth selling and small tubers that are free from pest attacks; Tubers fit for sale are healthy tubers measuring > 100 g; Tubers unfit for sale are tubers attacked by pest and small tubers; Small tubers are tubers weighing < 100 g. a Number followed by the same letter on the same line are not significantly different on the 5% DMRT follow-up trial.

crowns. This pigment can also be extracted from several plant organs from tubers, leaves to fruit, such as purple sweet potato (Saati, 2016). Purple sweet potato can be used as a natural dye. The use of natural dyes such as anthocyanins is increasingly in demand because it can reduce the use of synthetic dyes which are toxic and not environmentally friendly. Anthocyanins are also used in the manufacture of nutritional supplements because they have many positive impacts on human health. In Japan, anthocyanins are not only used as food coloring, but also used as paper coloring (Awobana paper) (Bechtold and Mussak, 2009).

CONCLUSION

Provision of 2,000 ppm of growth regulator applied at 4, 8, and 12 WAP was not able to increase vegetative growth and tuber yield components. Application of K_2O fertilizer 60 kg ha^{-1} to 180 kg ha^{-1} has not been able to increase tuber growth and yield. There are differences in tuber production between clones. MSU 03028-10 clone had the best tuber yield components, namely total tubers, healthy tubers, unfit tubers and small tubers. Clone MSU 03028-10 had the longest stem and the highest number of leaves. There was no interaction between the two and three treatment factors in increasing growth and tuber yield components.

REFERENCES

Assyakur, A.R. (2009). Evaluation of agro-climatic zones from the Schmidt-Fergusson classification using geographic information system (GIS) applications. *J. Incandescent 3:17-22*.

Bechtold, T. & Mussack, R. (2009). Handbook of Natural Colorants. Willey, United States.

Bradshaw, J.E. & Ramsay, G. (2009). Potato origin and production. In: Singh, J., Kaur, L. (Eds.), Advances in Potato Chemistry and Technology. Academic Press, Burlington, pp. 1–26.

Ginting E., Utomo, J.S., Yulifianti, R., Yusuf, M. (2011). Potential of purple sweet potato as a functional food. *Science and Technology of Food Plants 6:116-138*.

Jusuf, M., Rahayuningsih, S.A., Wahyuni, T.S. & Restuono, J. (2011). Clones of Hope RIS 03063-05 and MSU 03028-10 Prospective Superior Varieties of Purple Sweet Potato Rich in Anthocyanin. Research Institute for Legumes and Tubers.

Krisantini & Tija, B.O. (2011). Guide to the Use and Application of Growth Regulatory Substances in Ornamental Plants. Bogor: Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University.

Sustainable, E.G. (2011). The role of growth regulators in plant propagation through tissue culture. *Journal of AgroBiogen 1:63-68*.

Nedunchezhiyem, M., Byju, G. & Jata, S.K. (2012). Sweet potato agronomy. *Fruit Vegan. Cereal Sci. Biotech 6:1-10*.

Pahlevi, R.W., Guritno, B. & Suminarti, N.E. (2016). The effect of the combined proportions of nitrogen and potassium fertilization on growth, yield and quality of sweet potato (Ipomea batatas (L.) Lamb) Cilembu variety in the lowlands. *Journal of Plant Production 4(1):16-22*.

Rasyid, B., Samosir, S.R.S. & Sutomo, F. (2010). Response of maize (*Zea mays*) to various groundwater regimes and application of nitrogen fertilizers. Proceedings of the 2010 National Cereal Week. Center for Agricultural Research and Development Agency for Agricultural Research and Development.

Saati, E.A., Asiyah, R. & Ariesandy, M. (2016). Anthocyanin Pigments: Identification and Benefits for the Food and Pharmaceutical Industry. Malang Muhammadiyah University.

Saputro, B., Priatna, D., Rosadi, R. & Miyazawa, N. (2023). Spatial analysis of paddy field change in Purwakarta Regency, West Java, Indonesia. *Indonesian Journal of Applied Environmental Studies 4(1): 22-29*.

Sucharat. L., Aroonsri, P., Teerasak, D., Wanwisa, L. & Ratiya, K. (2016). Improvement of chemical stability and activities of anthocyanins by complexation. *Current Bioactive Compound 12(1):17-24*.

Suwarto, A., Setyawan, D. & Septariasari. (2006). Growth and yield of two sweet potato clones in intercropping with maize. *Bull. Agron 34: 87-92*.

Wandana, S., Hanum, C. & Sipayung, R. (2012). Growth and yield of sweet potatoes with potassium and tricontanol fertilizers. *Online Journal of Agroekotechnology 1(1)* http://jurnal.usu.ac.id/index.php/agroekotechnology/article/view/670/477 (Accessed 24 June 2014).

Werlein, H.D., Kutemeyer, C., Schatton, G., Hubbermann, E.M. & Schwarz, K. (2005). Influence of elderberry and black currant concentrates on the growth of microorganisms. *Food Control 16:729-733*.

Zelelew, D.Z. & Ghebreslassie, B.M. (2015). Response of potato varieties to potassium levels in Hamelmalo area, Eritrea. *Journal of Plant Studies 5:11-19*.

InJAST
Volume 4, Number 2, October 2023
Pages: 107-110

P - ISSN: 2722 - 0133
E - ISSN: 2722 - 0141
DOI: 10.33751/injast.v4i2.9115

Investigating the relationship between population growth and temperature change in Nabire and Paniai Regencies

EKKY AMIRAL FAQI[1,*], LEO ARIE WIBAWA[2]

[1]BMKG-Meteorological Station of Enarotali, 39FJ+7C8, Awabutu, Paniai Timur, Paniai Regency, Papua 98726, Indonesia
[2]BMKG-Meteorological Station of Nabire, FMX+J6F, Morgo, Nabire, Nabire Regency, Papua 98811, Indonesia

Corresponding author: *admiral.ekky@gmail.com*

Submitted 28 October 2023 ; Accepted 28 November 2023

ABSTRACT

Regional development is a priority programme of the government of the Republic of Indonesia. The region that has received significant development is the province of Papua. The form of development in Papua Province is the division of a new autonomous region (DOB). The formation of new autonomous regions encourages development in newly created areas, especially in urban areas. Cities that are increasingly developing can trigger the flow of urbanization so that the population increases. Increasing population affects climate parameters, especially air temperature. Temperature is expected to increase as a result of an increase in the number of urban residents and the imbalance of energy in and out of the earth. This study aims to determine the effect of population on variations in temperature in Nabire and Paniai Regencies. The data used are annual average, minimum, and maximum temperature data at the Nabire and Paniai Meteorological Stations. The data is displayed in graphical form, and the correlation is calculated to be analyzed descriptively. The results of the study show that there is a strong correlation between population growth and an increase in average and minimum average temperatures. While the average maximum temperature has a weak relationship to population growth.

ABSTRAK

Pembangunan daerah merupakan program prioritas pemerintah Republik Indonesia. Wilayah yang mendapat pembangunan signifikan adalah Provinsi Papua. Bentuk pembangunan di Provinsi Papua adalah pemekaran daerah otonom baru (DOB). Pembentukan daerah otonom baru mendorong pembangunan di daerah pemekaran, khususnya di perkotaan. Kota yang semakin berkembang dapat memicu arus urbanisasi sehingga jumlah penduduk semakin meningkat. Pertambahan jumlah penduduk mempengaruhi parameter iklim khususnya suhu udara. Suhu diperkirakan akan meningkat akibat bertambahnya jumlah penduduk perkotaan dan ketidakseimbangan energi yang masuk dan keluar bumi. Penelitian ini bertujuan untuk mengetahui pengaruh jumlah penduduk terhadap variasi suhu di Kabupaten Nabire dan Paniai. Data yang digunakan adalah data suhu rata-rata, minimum, dan maksimum tahunan di Stasiun Meteorologi Nabire dan Paniai. Data ditampilkan dalam bentuk grafik, dan korelasinya dihitung untuk dianalisis secara deskriptif. Hasil penelitian menunjukkan adanya korelasi yang kuat antara pertumbuhan penduduk dengan peningkatan suhu rata-rata dan minimum rata-rata. Sedangkan rata-rata suhu maksimum mempunyai hubungan yang lemah terhadap pertumbuhan penduduk.

Keywords: *climate, resident, temperature, population growth, variation*

INTRODUCTION

The Government of the Republic of Indonesia has authorized the formation of new autonomous regions in Papua, namely Central Papua, South Papua, and Highlands Papua (Setkab, 2022). The establishment of a new autonomous region encourages infrastructure development, especially in urban areas. City development can trigger urbanization, which is seen as a determining factor for a city to develop both physically and socially (Harahap, 2013). Urbanization causes an increase in the number of residents in urban areas. Population has a dominant impact on climate (Rai et al., 2019).

One of the climate parameters affected by population growth is surface air temperature. The temperature is predicted to increase in the future (IPCC, 2013). An increase in surface temperature is an indicator of global warming as a result of an imbalance of incoming and outgoing energy in the Earth's atmosphere (Puspitasari & Surendra, 2016). An increase in population results in a diversity of activities among city dwellers, which directly or indirectly affect parameters of the local climate, especially temperature (Mas'at, 2008). The THI (thermal comfort index) states that the closer to the city center, the greater the percentage of discomfort (Wati & Fatkhuroyan, 2017).

Research related to variations in surface temperature has been carried out in various regions. Annual temporal variations show that there is an increase in temperature over a 30-year period in Java by 0.11−1.24°C (Prasetyo et al., 2021). The significant development of the DKI Jakarta area has caused surface air temperatures to increase by 0.17°C from the annual average in the last 28

years, with urban areas experiencing a greater increase at 0.8°C (Mas'at, 2009). The increase in the number of motorized vehicles in the DKI Jakarta megacity is rapidly increasing the humidex heat index (Wati & Nasution, 2018).

Research that has been conducted in various regions has shown similar results: an increase in surface temperature every year. Therefore, it is necessary to conduct research on the effects of variations in surface temperature on rapid development in Central Papua. The purpose of this study was to determine the relationship between temperature and population growth in Central Papua so that the results of the research can be taken into consideration in the development of a new autonomous region in Central Papua.

METHODS

Research Location

The districts of Nabire and Paniai are the site of the research (Figure 1). Paniai Regency is situated in the Weyland Mountains, whilst Nabire Regency is situated at Cendrawasih Bay. Nabire district is expected to represent urban and lowland temperature variations, while Paniai district represents rural and highland temperature variations.

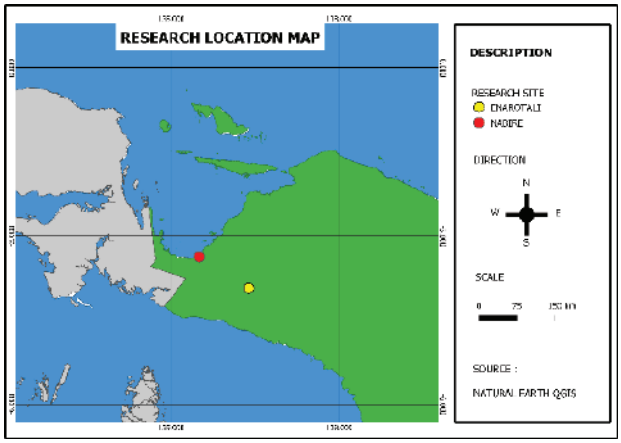


Figure1. Map of research location in Enarotali and Nabire Meteorogical Stations, Papua.

Data Analysis

The data used are temperature data from observations at the Nabire and Enarotali Paniai Meteorological Stations, as well as population data from the Nabire and Paniai Central Statistics Agency from 2007 to 2021. The temperature data used is average, maximum, and minimum air temperatures.

Temperature and population data are displayed in graphical form and the correlation is calculated (Table 1). The formula for calculating the correlation is as follows:

$$r = \frac{n\Sigma xy - \Sigma x\Sigma y}{\sqrt{n\Sigma x^2 - (\Sigma x^2)}\ \sqrt{n\Sigma y^2 - (\Sigma y^2)}}$$

Where:
r = correlation coefficient x and y
x = average temperature
y = number of population

Table 1. Correlation coefficient description (Sugiyono, 2012)

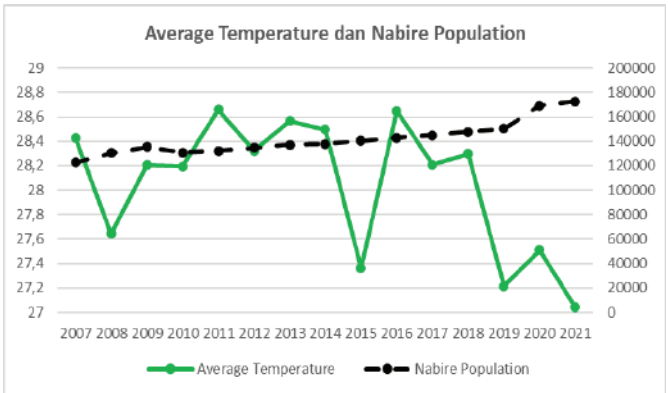
R value (correlation)	Remarks
0.00 - 0.199	Very Weak
0.20 - 0.399	Weak
0.40 - 0.599	Medium
0.60 - 0.799	Strong
0.80 - 1.000	Very Strong

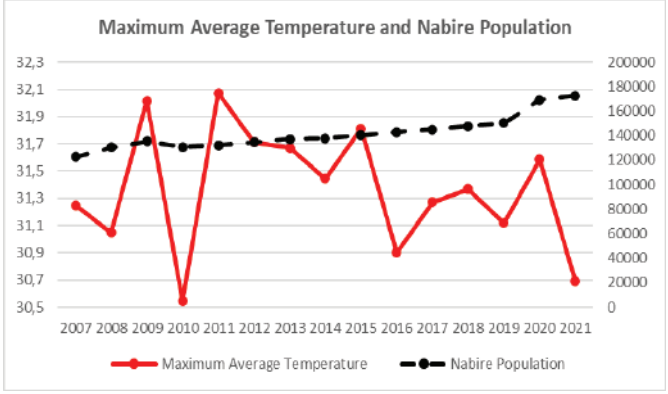
RESULTS AND DISCUSSION

Air Temperature Variation in Relation to Nabire Regency Residents' Numbers

Graphs and coefficients of correlation different findings are revealed by the temperature in Nabire Regency (Table 2). In contrast to the average lowest temperature, which tends to rise, the average maximum temperature and average temperature vary from year to year (Figure 2).

As illustrated in Figure 2, the correlation between temperature and population density in Nabire Regency ranges from inversely to directly proportional. Population increase and average temperature have a reasonably strong inverse relationship (r = -0.63). Population growth and maximum temperature have a





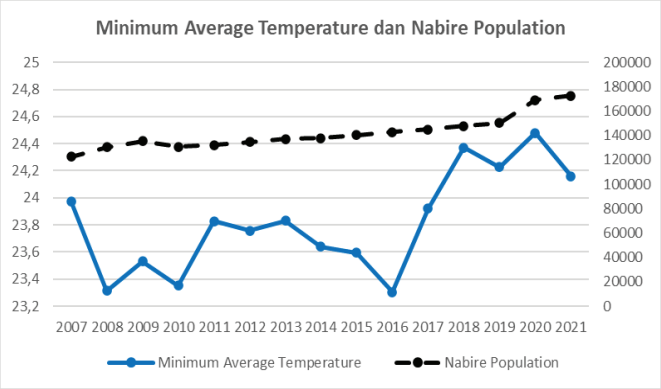


Figure 2. Graph of the relationship between average temperature, maximum temperature, minimum temperature, and population in Nabire Regency.

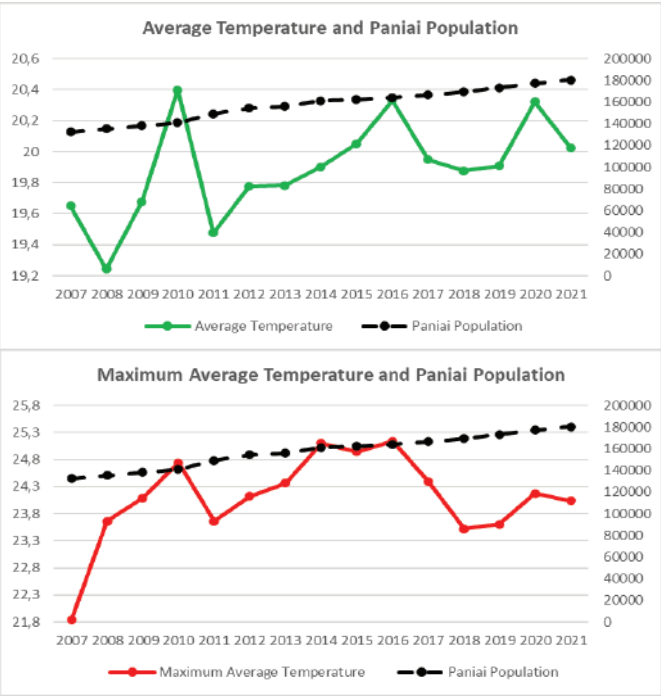
weak inverse relationship (correlation value = -0.21). The lowest air temperature illustrates a straight proportional relationship. There is a strong direct association between population increase and the minimum temperature, as indicated by the correlation value of 0.64 (Table 3).

Table 2. Correlation coefficient of average, maximum, and minimum temperature to the number of residents in Nabire Regency.

Corellation Coeficient	
Average temperature	0.53
Average maximum temperature	0.35
Average minimum temperature	0.79

Variation in Air Temperature According to Paniai Regency Residents' Numbers

Correlation coefficients and graphs Similar findings are shown by the Paniai district's air temperature. Annual trends indicate that minimum, maximum, and



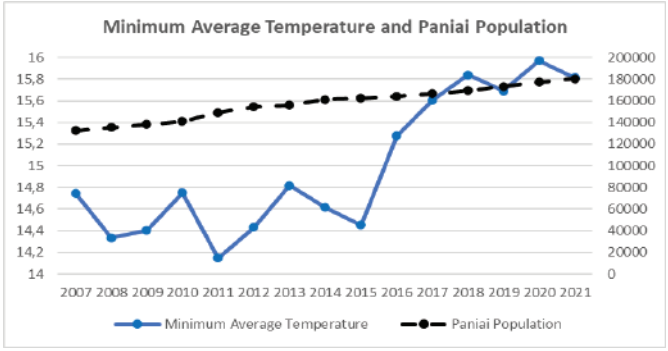


Figure 3. Graph of the relationship between average temperature, maximum temperature, minimum temperature, and population in Paniai Regency.

average temperatures tend to rise (Figure 3).

Based on Figure 3, there is a clear correlation between Paniai's population increase and air temperature. The average temperature has a relatively significant correlation (0.53) with itself, and it is directly proportional. With a correlation coefficient of 0.35, the average maximum temperature and population increase have a weak direct link. With a correlation coefficient of 0.79, the minimum average temperature and population increase have a significant direct proportionate relationship.

Table 3. Correlation coefficient of average, maximum, and minimum temperature to the number of residents Paniai Regency.

Corellation Coeficient	
Average temperature	-0,63
Average maximum temperature	-0,21
Average minimum temperature	0,64

CONCLUSION

Based on visual analysis and the correlation coefficient between population and air temperature, the following conclusion may be drawn:

In Paniai Regency, population growth is directly proportionate to rising average air temperature and has a high correlation with it; in Nabire Regency, the correlation is inverse but still reasonably strong. In the regencies of Paniai and Nabire, population growth and average maximum temperature have a poor association. In Paniai and Nabire Regencies, population growth is directly correlated with the average minimum temperature.

REFERENCES

Harahap, F.R. (2013). Dampak urbanisasi bagi perkembangan kota di Indonesia. *Jurnal Society, 1(1), 35-45.* https://society.fisip.ubb.ac.id/index.php/society/article/view/40.

Intergovernmental Panel on Climate Change. (2013). Climate Change 2013: The physical science basis contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. New York: Cambridge University Press. https://www.ipcc.ch/site/assets/uploads/2018/03/WG1AR5_SummaryVolume_FINAL.pdf.

Mas'at, A . (2008). Dampak pembangunan terhadap variasi iklim di Jakarta. B*uletin BMKG, 4*, 2008.

Mas'at, A . (2009). Efek pengembangan perkotaan terhadap kenaikan suhu udara di Wilayah DKI Jakarta. *Jurnal Agromet., 23(1)*, 52-60. https://doi.org/10.29244/j.agromet.23.1.52-60

Prasetyo, S., Hidayat, U., Haryanto, Y.D., and Riama, N.F. (2021). Variasi dan trend suhu udara permukaan di Pulau Jawa. *Jurnal Geografi, 18(1), 60-68*. https://doi.org/10.15294/jg.v18i1.27622

Puspitasari, N., and Surendra, O. (2016). Analisis tren perubahan suhu udara minimum dan maksimum serta curah hujan sebagai akibat perubahan iklim. *SAINS: Jurnal MIPA dan Pengajarannya, 16(2), 66-72*.

Rai, M., Breitner, S., Wolf, K., Peters, A., Schneider, A., and Chen, K. (2019). Impact of climate and population change on temperature-related mortality burden in Bavaria, Germany. *Environmental Research Letters, 14, 1-12*. https://doi.org/10.1088/1748-9326/ab5ca6.

Sekretariat Kabinet Republik Indonesia. (2022). UU Nomor 15 Tahun 2022 tentang Pembentukan Provinsi Papua Tengah. Jakarta: Humas Setkab. https://setkab.go.id/pembentukan-tiga-provinsi-baru-di-papua/.

Sugiyono. (2012). *Statistika untuk Penelitian*. Bandung: CV. Alfabeta.

Wati, T., and Fatkhuroyan. (2017). Analisis tingkat kenyamanan di DKI Jakarta berdasarkan indeks THI (Temperature Humidity Index). *Jurnal Ilmu Lingkungan, 15(1), 57-63*. https://doi.org/10.14710/jil.15.1.57-63.

Wati, T., and Nasution, R.I. (2018). Analisis kenyamanan thermis klimatologis di Wilayah DKI Jakarta dengan menggunakan indeks panas (Humidex). *Widyariset, 4(1), 89-102*. https://doi.org/10.14203/widyariset.4.1.2018.89-102.

GUIDELINES FOR AUTHORS

Submission Preparation Checklist

As part of the submission process, authors are required to check off their submission's compliance with all of the following items, and submissions may be returned to authors that do not adhere to these guidelines.

- The submission has not been previously published, nor is it before another journal for consideration (or an explanation has been provided in Comments to the Editor).
- The submission file is in OpenOffice, Microsoft Word, or RTF document file format.
- Where available, URLs for the references have been provided.
- The text is single-spaced; uses a 12-point font; employs italics, rather than underlining (except with URL addresses); and all illustrations, figures, and tables are placed within the text at the appropriate points, rather than at the end.
- The text adheres to the stylistic and bibliographic requirements outlined in the Author Guidelines.

Author Guidelines

The Indonesian Journal of Applied Environmental Studies will publish original work by:

- Indonesian or foreign scientists on any aspect of Indonesian environmental sciences, including environmental chemistry, environmental biology, ecology geoscience and environmental physics. Appropriate subjects include basic and applied research on atmospheric, terrestrial and aquatic environments pollution control and abatement technology, conservation of natural resources, environmental health study and toxicology, environmental quality assessment, environmental standards and criteria.

The Indonesian Journal of Applied Environmental Studies will publish original work by:

- Enhances understanding of environmental needs in Indonesia
- Improve environmental intervention and management in Indonesia
- Enhances the understanding of Indonesia's environmental management

The Journal language will be in English with abstracts in Bahasa Indonesia as well as English. Authors of full papers are encouraged to provide a Bahasa Indonesia/English translation of their abstract.

Papers and Short Communications

Full Research Papers (2,000-7,000 words) and Short Communications (200-2,000 words) are invited on topics relevant to the Journal's focus, including:

- Environmental chemistry
- Environmental biology
- Ecology geoscience
- Environmental physics
- Basic and applied research on atmospheric
- Terrestrial and aquatic environments pollution control and abatement technology
- Conservation of natural resources
- Environmental health study and toxicology
- Environmental quality assessment
- Environmental standards and criteria

The Journal will not accept descriptions of new species, subspecies or other taxa.

How to Submit a Manuscript

Manuscripts should be submitted through online submission system (OJS) at

https://journal.unpak.ac.id/index.php/InJAST/index

In the cover letter, the Lead Author must confirm that:

- The submitted manuscript has not been published elsewhere
- All of the authors have read the submitted manuscript and agreed to its submission
- All research was conducted with the necessary approval and permits from the appropriate authorities

Review and editing

All contributors in English are strongly advised to ensure that their spelling and grammar is checked by a native English speaker before the manuscript is submitted to the Journal. The Editorial Team reserves the right to reject manuscripts that are poorly written.

Submission is only in English and the Journal secretariat will undertake a preliminary review of all manuscripts for suitability of content and format. Manuscripts that are rejected at this stage will not be sent for peer review and translation.

Manuscripts that pass through the preliminary review will be peer reviewed by a minimum of two reviewers. Authors are welcome to suggest appropriate reviewers.

Proofs will be sent to authors as a portable document format (PDF) file attached to an e-mail note. Corrected proofs should be returned to the Editor within 3 days of receipt. Minor corrections can be communicated by e-mail.

The Editorial Team also welcomes contributions to the other sections of the journal:

News

Concise reports (<300 words) on news of general interest to the study and management of Indonesia's environment. News reports may include,

- Announcements of new initiatives; for example, the launch of new projects, conferences or funding opportunities.
- Announcements of important new reports or other publications related to Indonesian environmental management.
- Summaries of important news from an authoritative published source; for example, new research technique, or a recent development in applied environmental management.
- Summaries and analysis of new policies, decrees and laws relevant to the Indonesian environmental management.

Letters to the Editor

Informative contributions (<650 words) in response to material published in the Journal.

Preparation of manuscripts

Full papers follow the style and format of papers published in the journal Conservation Biology. Authors should consult examples in Conservation Biology for guidance on general style.
Contributions should be in UK English, double-spaced and in 'doc, 'rtf' or 'wpd' format, preferably as one file attached to one covering e-mail.

The cover page should contain; The title and full mailing address, e-mail address and address of the Lead Author and all additional authors.

Contributing Papers should contain the following sections and be arranged in the following order: Abstract, Introduction, Methods, Results, Discussion, Acknowledgments, Literature Cited. Tables, figures and Plates (including legends), if included, should follow the Literature Cited.

All pages should be numbered consecutively. Do not number section headings or subheadings.

Title: This should be a succinct description of the work, in no more than 20 words.

Abstract: Abstracts should only be submitted for Full Papers. This should describe, in 100-300 words, the aims, methods, major findings and conclusions. It should be informative and intelligible without reference to the text, and should not contain any references or undefined abbreviations. Authors are encouraged to submit and English translation of Indonesian text and an Indonesian translation of an English text.

Keywords: From five to eight pertinent words, in alphabetical order.

Literature cited in text: Enclose citations in text in parentheses e.g. "Asian tapirs are no elephants when it comes to seed dispersal (Campos-Arceiz et al., 2011)."

Use an ampersand (&) between author surnames when the citation is parenthetical: (Traeholt & Idris, 2011).

When a citation is not parenthetical, use "and": "Our results agree with the predictions of Wolf and Rhymer (2001)."

For citations with more than two authors, use et al.: (Campos-Arceiz et al., 2011). Do not italicize et al.

List parenthetical citations in alphabetical order and chronologically from oldest to most recent and separate entries with a semicolon: (Campos-Arceiz et al., 2011; Geissman, 2009, 2010).

Separate the years with commas when citing multiple papers by the same author: (Corlett, 2007, 2010; Geissman, 1984, 1995, 1999, 2000).

"In press" means the cited paper has been accepted unconditionally for publication. Provide the year of publication in the text (Bird, 2010) and in Literature Cited section provide the volume number, and substitute "in press" for page numbers (Bird, I.M. 2010. Nesting success in arid lands. Conservation Biology 24: in press.).

Papers in review must be cited as unpublished and should not appear in the Literature Cited section.

Use an initial for the first (given) name and spell out the last name (surname) for other sources of unpublished data or information: (R. Fowler, unpublished data; M.E. Soulé, personal communication).

Software: capitalize the first letter only if the name of the program is a word (e.g., Vortex, ArcGIS). If the name of the program is not a word, use all capital letters (e.g., SAS).

The following are examples of Literature Cited house style:

Campos-Arceiz, A. and R.T. Corlett (2011). Big animals in a shrinking world—studying the ecological role of Asian megafauna as agents of seed dispersal. *Innovation* 10: 50–53.

Campos-Arciez, A., Larringa, A.R., Weerasinghe, U.R., Takatsuki, S., Pastorini, J., Leimgruber, P., Fernando, P. and L. Santamaria (2008). Behavior rather than diet mediates seasonal differences in seed dispersal by Asian elephants. *Ecology* 89: 2684–2691.

MacArthur, R.H. & Wilson, E.O. (1967). The Theory of Island Biogeography. Princeton University Press, Princeton, USA.

Sutherland, W.J. (ed.) (1998). Conservation Science and Action. Blackwell Science, Oxford, UK.

Beck, B.B., Rapaport, L.G. & Stanley Price, M.R. (1994). Reintroduction of captive-born animals. In Creative Conservation: Interactive Management of Wild and Captive Animals (eds P.J.S. Olney, G.M. Mace & A.T.C. Feistner), pp. 265-286. Chapman & Hall, London, UK.

Traeholt, C., Bonthoeun, R., Rawson, B., Samuth, M., Virak, C. and Sok Vuthin (2005). Status review of pileated gibbon, Hylobates pileatus and yellow-cheeked crested gibbon, Nomascus gabriellae, in Cambodia. Fauna & Flora International, Phnom Penh, Cambodia.

Sun H. (2000). Status of the tiger and its conservation in Cambodia. MSc thesis, University of Minnesota, Minneapolis, USA.

IUCN (2010). 2010 IUCN Red List of Threatened Species. http://www.redlist.org [accessed 1 February 2011].

Biography: This should describe the main research interests of all authors (<150 words total), apart from what is obvious from the subject of the manuscript and the authors' affiliations.

Tables, figures and plates: These should be self-explanatory, each on a separate page and with an appropriate caption. Figures can be submitted in colour as well as in black and white. The Editorial Team may decide to convert coloured figures into black and white should it be necessary due to printing cost and without diluting the message. Plates (black and white only) will only be included in an article if they form part of evidence that is integral to the subject studied (e.g., a photograph of a rare species), if they are of good quality, and if they do not need to be printed in colour.

Appendices: Lengthy tables, and questionnaires are discouraged. In special circumstances these may be made available for viewing online.

Species names: The first time a species is mentioned, its scientific name should follow in parenthesis and in italics: e.g., Asian elephant (*Elephas maximus*). English names should be in lower case throughout except where they incorporate a proper name (e.g., Asian elephant, Cookson's wildebeest, long-billed vulture).

Abbreviations: Full expansion should be given at first mention in the text.

Units of measurement: Use metric units only for measurements of area, mass, height, etc.

The Indonesian Journal of Applied Environmental Studies (InJAST) is co-published biannually by the Graduate School of Environmental Management at the Pakuan University, Bogor, Indonesia, and Perhimpunan Cendikiawan Pemerhati Lingkungan Indonesia, the Indonesian Association of Environmentalist Scholars (PERWAKU), in collaboration with Belantara Foundation. The Graduate School of Pakuan University, through its Study Programme of Environmental Management, is having a vision as a center for developing a qualified, tough and dignified human resources. PERWAKU is having a vision of towards environmentally friendly Indonesia.

Indonesian Journal of Applied Environmental Studies

journal.unpak.ac.id
Volume 4 • Number 2 • October 2023
P - ISSN : 2722 - 0133
E - ISSN : 2722 - 0141

P-ISSN: 2722 - 0133 E-ISSN: 2722 - 0141

9 772722 013002 9 772722 014009

Pakuan University

Supported by Belantara FOUNDATION