BILINGUAL PUBLISHING GROUP

Journal of Environmental & Earth Sciences

https://journals.bilpubgroup.com/index.php/jees

ARTICLE

Study Assessment of Soil and Water Quality Conditions on Barren Agricultural Lands in Tropical Regions

Ari Handriatni[1], Heri Ariadi[2*], Farchan Mushaf Al Ramadhani[1], Syakiroh Jazilah[1], Sajuri[1]

[1] *Department of Agrotechnology, Faculty of Agriculture, University of Pekalongan, Pekalongan 51119, Indonesia*

[2] *Department of Aquaculture, Faculty of Fisheries, University of Pekalongan, Pekalongan 51119, Indonesia*

ABSTRACT

Barren land is non-productive land that is difficult to use as a medium for integrated agricultural cultivation. The aim of this research is to determine the profile and feasibility status of land in barren agricultural areas quantitatively. The research method used was descriptive with purposive data collection. Data analysis included SQI and WQI parametric analyses. The research results indicate that the ideal soil parameter is only pH 7.5–7.7, while for water parameters it is pH 8.0–8.1, meeting water quality standards. SQI values range from 0.44 to 0.49 and WQI from 0.45 to 0.57. SQI and WQI values at the research site fall into the poor category, indicating difficulty in converting the land into agricultural use. SQI and WQI show a strong correlation as depicted in the model Y = 4.113 + 0.026 (R2 = 0.789). Correlation tests showed strong correlations in soil between redox potential and soil pH (0.449), and redox potential and organic matter (0.377). Weak correlations were found between cation exchange capacity and soil pH (0.009), and nitrate and total N (0.517). In water, strong correlations were found between water pH and nitrite (0.302) and ammonia (0.529). Additionally, water pH showed weak correlations with carbon dioxide (0.752) and organic matter (0.659). The values of soil and water parameters have an immediate impact on plant growth patterns. Therefore, integrated agricultural cultivation patterns need to be developed. In conclusion, empirically, the condition of barren land indicates poor land use feasibility. The poor profile and biophysical feasibility conditions of barren land are attributed to environmental pollution and runoff from other land areas.

Keywords: Biophysics; Plant; SQI; WQI

*CORRESPONDING AUTHOR:

Heri Ariadi, Department of Aquaculture, Faculty of Fisheries, University of Pekalongan, Pekalongan 51119, Indonesia; Email: ariadi_heri@yahoo.com

ARTICLE INFO

Received: 31 July 2024 | Revised: 26 August 2024 | Accepted: 4 September 2024 | Published Online: 29 September 2024

DOI: https://doi.org/10.30564/jees.v6i3.6977

CITATION

Handriatni, A., Ariadi, H., Al Ramadhani, F.M., et al., 2024. Study Assessment of Soil and Water Quality Conditions on Barren Agricultural Lands in Tropical Regions. Journal of Environmental & Earth Sciences. 6(3): 176–185. DOI: https://doi.org/10.30564/jees.v6i3.6977

1. Introduction

Crop cultivation is a significant agribusiness activity widely practiced in tropical regions [1]. Indonesia, as the largest tropical country in Southeast Asia, exhibits diverse agricultural land characteristics [2]. One type of agricultural land found in Indonesia is barren land. Barren land can be defined as critical land that is difficult to use for intensive agricultural cultivation [3]. Marginal land is often found in barren agricultural areas and agricultural areas adjacent to household activity locations [4].

The occurrence of barren land can be attributed to continuous intensification of chemical usage in those areas [5]. Several heavy metal elements such as Pb, Cd, Hg, and Cr which are intense in the soil will affect the formation of marginal agricultural land [6]. Additionally, intense sedimentation processes and prolonged droughts also influence the formation of critical land [3]. These critical agricultural lands significantly disrupt farming activities since not all commodities can be cultivated in such conditions. Moreover, barren land also exhibits very low harvest productivity, making it highly unsuitable for agricultural land use [5].

Agricultural land in tropical regions can recover if there is a structured reduction in land use intensity [7]. Furthermore, this recovery process requires a long time and physiological adaptation of some plants to effectively utilize the land [8]. This implies that critical land requires time and stages to revert to its original state for integrated agricultural land use [9]. This is due to the semi-comfortable nature of agricultural land, which causes a long process of purifying the soil from the impact of environmental pollution [10].

Barren agricultural land has an impact on the reproducibility of crop cultivation in the area [2]. From an empirical study related to the performance of rice cultivation on barren land, it can only produce a harvest productivity of 1,000 kg/ha [11]. Marginal land also affects the level of biodiversification of rice plant species that can be cultivated only 5 species [12]. Barren land also affects the ecological characteristics of the environment in the area [13]. The existence of massive marginal land is also closely related to the impact of climate change in tropical regions [14]. Therefore, it is crucial to assess the feasibility status of land based on soil and water quality parameters to determine its suitability for agricultural activities.

Based on the aforementioned background, the objective of this study is to quantitatively determine the profile and feasibility status of barren agricultural lands. It is hoped that the findings of this research can be used as a reference for more comprehensive land management based on existing land feasibility analyses.

2. Methods

2.1 Research location

The data collection for this research was conducted in barren agricultural lands in Wonopringgo Village, Pekalongan (109°27'30"–109°28'13" and 7°50'–7°50'84"). Data collection was carried out at three different locations (**Figure 1**), considering the differences in land characteristics. The ecological profile of the sampling locations included areas of paddy irrigation flow, active agricultural lands, and semi-permanent lands.

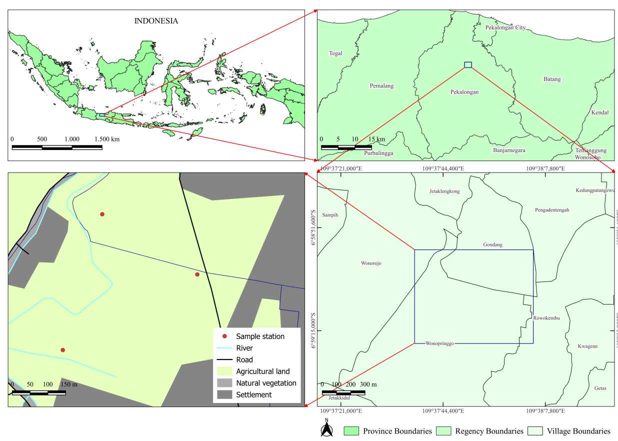

Figure 1. Sampling location map.

2.2 Sampling parameters

The data samples were obtained from three different sampling locations. At each sampling location, water and soil samples were collected periodically. Soil quality parameters observed included soil type and texture measured using a hydrometer, as well as soil pH, redox potential, organic carbon (OC), organic matter (OM), and cation exchange capacity (CEC) measured using APHA methods [15]. Total nitrogen (N), C/N ratio, and nitrate (NO_3) parameters were measured using the Tan method [16].

Water quality parameters observed included water pH measured with a Eutech EC-pHtest30 pH tester, salinity measured with an ATAGO Master IP65 refractometer, dissolved oxygen and water temperature measured with a YSI550i DO Meter. Other parameters included carbon dioxide (CO_2), nitrate (NO_3), orthophosphate (PO_4), ammonia (NH_3), Chemical Oxygen Demand (COD), Total Organic Matter (TOM), alkalinity, and nitrite (NO2) measured using water quality assessment methods [15]. Data collection for soil and water quality was conducted both in situ and ex situ.

2.3 Data analysis

The description of water and soil quality data was done narratively. The research results were tested using non-parametric correlation tests to identify relationships between variables. Statistical analysis in this study was conducted using Microsoft Excel 2011 and SPSS version 19.02 software. The analysis results were then used to draw conclusions from the analysis.

2.4 WQI and SQI analysis

The Water Quality Index (WQI) and Soil Quality Index (SQI) data are estimated based on the equation by Ma [17]:

$$WQI/SQI = \sum_{i=1}(WkVFk) \tag{1}$$

$$VFk = \sum_{i=1}(AkiPij) \tag{2}$$

Where: *WQI*/*SQI* is the water/soil quality index; *Wk* is the weight of the *k* variable; *VFk* is the principal component score; *Aki* is the weight of the variable *i*; *Pij* standard coefficient; *i* is a variable; and *j* is the maximum standard variable.

The score values on the WQI and SQI values are grouped by class using the *Sturges* formula [18]:

$$Sturges formula : n_c = 1 + 3.3Log10(N) \tag{3}$$

$$Class range : h = A/n_c \tag{4}$$

Where: n_c is the number of classes, N is the value of the observation result, *A* is the data range, and *h* is the class range. Furthermore, the calculation results from the formula are classified into ranks I to IV, where rank "I" is the *excellent* category.

From **Table 1** depicts the *Soil Quality Index* (SQI) and *Water Quality Index* (WQI) values at an object site. The SQI and WQI values are based on the classification results of existing value ranges.

3. Results and discussion

3.1 Soil parameters

The soil parameters at the research site are considered quite extreme based on the profile of soil physics and chemistry parameters (**Table 2**). The only soil parameter that is ideal ranges from pH 7.5 to 7.7. Other parameters such as redox potential, total nitrogen (N), organic matter, cation exchange capacity, and nitrate tend to be low, indicating that the land here is infertile. The infertility of the soil at the research site is due to nutrient deficiencies and the aridity of the land.

The soil characteristics at the research location are described as sand and clay with a low percentage of tightness (**Table 2**). Clay soil has a low water solubility level making the few solubility of nutrients [19]. Sand soil tends to have a low fertility level due to minimal nutrient solubility [20]. Both types of soil are not ideal when used as a medium for cultivating paddy, vegetables, and fruits [19–21]. Sand and clay soils are more suitable for use as a medium for cultivating aquatic plants with an integrated control system [22]. The presence of sand and clay soil types in highland areas triggers nutrient porosity which causes aridity in the soil layer structure [23].

Barren agricultural land triggers nutrient deficits, thereby affecting soil productivity profiles [24]. Soils have a varied capacity to absorb nutrients [13]. On average, barren land has dry and nutrient-poor soil characteristics [21]. Additionally, the levels of cation and anion exchange capacities tend to be low due to the lack of minerals in barren land [24].

3.2 Water parameters

The water quality parameters at the research site also tend to be poor to support agricultural cultivation activities. The water quality parameter that meets the standard for agricultural business cultivation is only pH (8.0–8.1). Other parameters such as nitrite, carbon dioxide, nitrate, phosphate, ammonia, COD, and organic matter tend to be very low (**Table 3**). The poor water quality parameters are due to the water sources flowing at the research site having a deficient nutrient profile.

Table 1. Table of suitability of SQI and WQI values.

The value of WQI	Water/soil conditions	Interval classes	The value of SQI
> 0.80	Excellent	I	>0.75
0.60 < WQI < 0.80	Good	II	0.50 < SQI < 0.75
0.30 < WQI < 0.60	Poor	II	0.25 < SQI < 0.50
0.05 < WQI < 0.30	Badly	IV	0.03 < SQI < 0.25

Table 2. Soil quality parameters at the research location.

Location	Soil parameters									
	pH	Redox	O.C	N total	OMG	CEC	NO_3	% sand	% silt	% clay
Station 1	7.7 ± 0.11	19.08 ± 6.33	0.45 ± 0.19	0.35 ± 0.04	0.93 ± 0.21	23.55 ± 14.12	2.22 ± 2.12	31 ± 18.43	39 ± 12.24	16 ± 7.41
Station 2	7.5 ± 0.12	11.43 ± 6.89	0.33 ± 0.25	0.25 ± 0.08	0.87 ± 0.21	26.75 ± 15.10	2.31 ± 2.22	29 ± 19.21	40 ± 12.27	19 ± 7.47
Station 3	7.5 ± 0.12	19.75 ± 7.11	0.52 ± 0.20	0.28 ± 0.08	0.93 ± 0.25	28.75 ± 14.45	3.07 ± 2.37	29 ± 18.25	42 ± 12.30	17 ± 7.56

Water quality parameters are crucial to support agricultural cultivation activities as they contribute to the addition of external nutrients [25]. Ideal water is neutral in pH and has a balanced abundance of mineral elements [26]. Water in plants is also utilized as a medium for nutrient transport [27]. Poor water quality will affect the growth patterns of plants in that location [25].

The *Soil Quality Index* (SQI) is used as an analytical method to classify and determine the status of land conditions [29]. Poor-quality land is highly unsuitable for agricultural and livestock activities. To improve poor land conditions, fertilization processes or land recovery from chemical use can be undertaken [13]. Good land is characterized by a balanced composition of minerals and nutrients [30].

3.3 Soil Quality Index (SQI)

The *Soil Quality Index* (SQI) values at the research site range from 0.44 to 0.49, showing variability (**Figure 2**). The range of values from 0.44 to 0.49 falls within Interval Class 2, indicating that the soil condition at the research site falls into the ”poor” category or tends to be poor. This classification illustrates that the soil condition at the research site is slightly contaminated and has a low level of land productivity. The contamination of agricultural land and the low level of land productivity are caused by high levels of land pollution activities in that location. Intensive use of chemicals and household waste runoff affect the level of agricultural land pollution [28].

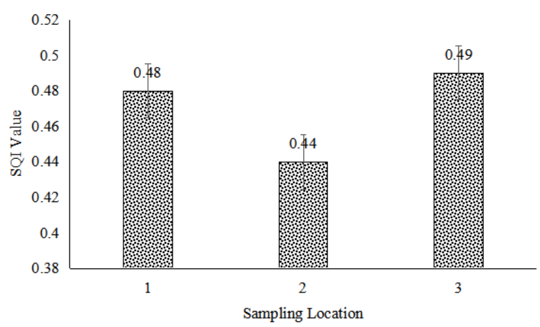

Figure 2. SQI value of the land where the research is located.

3.4 Water Quality Index (WQI)

The *Water Quality Index* (WQI) values at the research site range from 0.45 to 0.57, showing variability (**Figure 3**). The range of values from 0.45 to 0.57 falls within Interval Class 2, indicating that the water condition at the research site falls into the “poor” category. The poor water condition at the research site is due to contamination from upstream sources of the river. Additionally, pollution from agricultural lands also contributes to the contamination process in the waters of the research site. Water is a medium that readily dissolves, making it highly susceptible to interacting with pollutants and contaminants [31].

The condition of the *Water Quality Index* (WQI) is essential for mapping water conditions at a cultivation site [32]. When the Water Quality Index (WQI) is not ideal, a recovery process can be implemented through liquid purification [25]. Water that does not meet standards will be difficult to use as a medium or supportive factor in integrated agricultural activities [33]. In agricultural activities, both the quantity and quality of water are prioritized as essential factors [34].

The relationship between SQI and WQI values was compared using linear regression in **Figure 4**. This means that 79% of the WQI value in barren agricultural lands is

Table 3. Water quality parameters at the research location.

Location	Water parameters								
	Temperature	pH	NO_2	CO_2	NO_3	PO_4	NH_3	COD	OMG
Station 1	26.5 ± 1.88	8.0 ± 0.61	0.012 ± 0.68	0.006 ± 0.11	0.022 ± 0.45	0.057 ± 0.15	0.041 ± 0.19	226.25 ± 25.12	51.05 ± 8.22
Station 2	26.8 ± 1.87	8.1 ± 0.69	0.037 ± 0.64	0.016 ± 0.13	0.074 ± 0.40	0.078 ± 0.17	0.027 ± 0.18	205.34 ± 24.25	63.15 ± 8.36
Station 3	27.1 ± 1.80	8.0 ± 0.62	0.025 ± 0.62	0.010 ± 0.15	0.081 ± 0.47	0.057 ± 0.19	0.032 ± 0.19	333.22 ± 25.25	55.40 ± 8.25

influenced by the SQI value, while the remaining 21% is affected by other factors. The strong influence of SQI on WQI indicates a close relationship between soil and water conditions in the natural ecosystem. Regions with critical and polluted land conditions will affect water conditions inclusively [24].

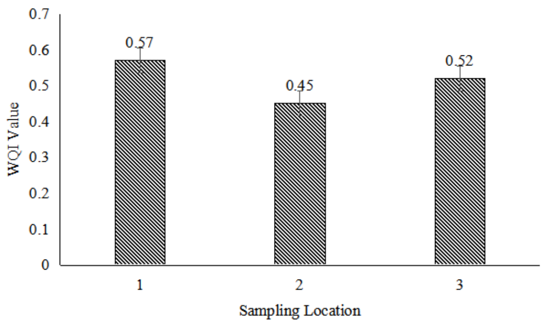

Figure 3. WQI value of the land where the research location is located.

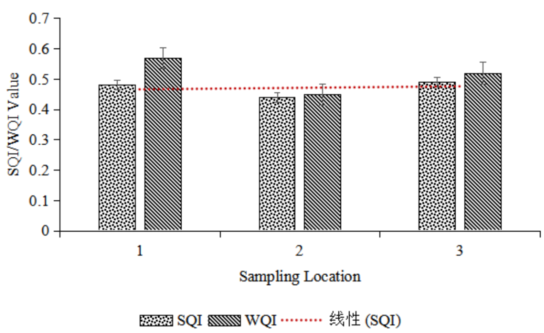

Figure 4. The relationship between the influence of SQI values on WQI and their correlation.

In fertile agricultural land, the primary indicators considered are soil condition, followed by water quality and air temperature stability [35]. Fertile soil will influence the abundance of nutrients available for plant growth [3]. Good quality and quantity of water will affect the availability of micronutrients for plants [36]. The quality of soil and water cannot be separated in crop maintenance practices in open areas [24].

3.5 Relationship of soil and water parameters

Based on the correlation test results, soil pH, redox potential, cation exchange capacity, organic matter, nitrate, and total nitrogen were found to have varying degrees of correlation (**Table 4**). Redox potential with soil pH (0.449) and redox potential with organic matter (0.377) showed a strong correlation. Meanwhile, cation exchange capacity with soil pH (0.009) and nitrate with total nitrogen (0.517) showed a weak correlation. Other parameters did not show significant correlations.

The high impact of correlation between redox potential and soil pH on other soil quality parameters is because these two parameters are fundamental soil parameters. Soil pH affects soil physicochemical processes [37], while redox potential influences cation exchange capacity and soil mineral solubility [38]. The dynamics of soil pH and redox potential in agricultural land are generally influenced by liming processes [8].

Water parameters also show very minimal correlation levels with each other. Based on the correlation test results in **Table 5**, only water pH, phosphate, ammonia, nitrite, and carbon dioxide show correlations. Water pH has a strong correlation with nitrite (0.302) and ammonia (0.529). Furthermore, pH also has a weak correlation with phosphate (0.752), and carbon dioxide has a weak correlation with organic matter (0.659). Generally, it can be analyzed that water pH significantly influences the solubility of nutrients in aquatic ecosystems.

pH affects the nitrification process, impacting the dynamics of nitrite and nitrate concentrations [39]. Excessively basic pH can make ammonia toxic [40]. Additionally, water pH affects the phosphorus cycle in aquatic environments in a chain-like pattern [41]. This means that pH in aquatic ecosystems profoundly influences both the nitrification and phosphorus cycles comprehensively.

High concentrations of organic matter also affect the solubility of carbon dioxide in water [42]. Abundant or-

Table 4. Correlation test results of soil quality parameters.

Variables	pH	Redox	O.C	N Total	OMG	CEC	NO_3	% sand	% silt	% clay
pH	1									
Redox	**0.449****	1								
O.C	0.391	0.293	1							
N Total	0.107	0.662	0.971	1						
OMG	0.201	**0.377****	0.902	0.078	1					
CEC	**0.009***	0.935	0.602	0.406	0.084	1				
NO_3	0.331	0.018	0.719	**0.517***	0.106	0.519	1			
% sand	−0.088	0.159	−0.902	0.943	0.219	0.796	0.739	1		
% silt	−0.218	0.173	0.175	0.019	0.023	0.204	0.015	0.935	1	
% clay	0.693	0.42	0.567	0.101	0.015	0.294	0.619	0.077	0.187	1

Table 5. Results of correlation test of water quality parameters.

Variables	Temperature	pH	NO_2	CO_2	NO_3	PO_4	NH_3	COD	OMG
Temperature	1								
pH	0.219	1							
NO_2	−0.118	**0.302****	1						
CO_2	0.109	−0.833	0.246	1					
NO_3	0.105	0.521	0.36	0.555	1				
PO_4	0.656	**0.752***	0.552	0.392	0.445	1			
NH_3	−0.693	**0.529****	0.228	0.593	0.139	0.439	1		
COD	0.67	0.205	0.793	0.629	0.333	0.704	0.592	1	
OMG	−0.458	−0.105	0.573	**0.659***	0.218	−0.437	0.205	−0.068	1

ganic matter increases oxygen consumption levels for decomposition processes, resulting in water conditions becoming oxygen-deficient [43]. Oxygen-deficient (hypoxic) waters lead to excessive carbon dioxide solubility [36]. Oversaturated carbon dioxide levels become toxic to plants [44].

The solubility of several elements such as carbon dioxide and metal elements will make the soil barren [45]. This also affects the level of soil fertility and low nutrient absorption [12]. Low nutrient absorption has an impact on the level of soil fertility and plant cultivars that can grow [46]. The best alternative to this condition is to carry out a land recovery process by means of organic fertilization and reducing the intensity of land use [47]. This is done so that the soil can recover and acclimatize to environmental conditions [48].

The feasibility status of land for agricultural cultivation is influenced by the performance of biotic and abiotic environmental factors [49]. Soil and water are abiotic components of agricultural land that directly impact land suitability [3]. Therefore, managing abiotic components is crucial in integrated agricultural activities. Poor abiotic soil components prevent biotic elements from thriving or supporting optimal environmental balance [38].

Barren lands are extremely challenging for integrated agricultural cultivation. Poor abiotic environmental parameters significantly disrupt systematic plant cultivation processes [50]. This is evidenced by the correlation found in this research regarding the degradation of soil and water quality parameters. If soils in agricultural areas are contaminated and of poor quality, they will similarly impact the surrounding water conditions inclusively [51]. The coexistence of soil and water in the same zone greatly increases the potential for cross-contamination from existing pollutant wastes [26]. The existence of marginal land in the research area is also closely related to the existence of low rainfall. The results of data from the Pekalongan Regency Statistics in 2021 obtained a rainfall value of 27 mm/day. A rainfall value of 10-50 mm/day has a low level of water solubility and is poor in nutrients [52].

Lands in tropical regions should ideally exhibit better biophysical parameter profiles. Adequate sunlight exposure and sufficient rainfall make tropical soils more feasible [53]. However, tropical regions, synonymous with agrarian activities, affect unplanned crop cultivation cycles [54]. Consequently, there is a decline in land carrying capacity, leading to a shift in land performance to non-productive barren lands [7]. Consistent agricultural engineering activities are necessary to address this issue so that barren agricultural lands can undergo recovery [55].

4. Conclusions

The profile of barren agricultural land generally shows poor conditions when viewed through the concentration of abiotic environmental parameters. Empirically, the condition of barren land also shows a poor level of land use feasibility from the results of the SQI (0.44–0.49) and WQI (0.45–0.57) analysis. The profile and biophysical conditions of barren land are caused by environmental pollution and runoff from household waste. Therefore, synergy in barren land management by relevant stakeholders is needed.

Author Contributions

Conceptualization and methodology: A.H. and H.A.; analysis data: H.A., F.M., A.R., S.Y. and S.; writing original draft: H.A.; editing and visualization: F.M. and A.R.

Conflict of Interest

The authors declare no conflict of interest.

Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of Pekalongan University in 1 July 2024.

Data Availability Statement

This research data is confidential and becomes a research archive.

Funding

This research was funded by the Institute for Research and Community Service, University of Pekalongan through contract number 176/B.06.01/LPPM/III/2024 and the total funding budget was $614 for applied research activities in the 2024.

Acknowledgments

This research was funded by a grant research programe by LPPM Pekalongan University with contract number 176/B.06.01/LPPM/III/2024 and the Wonopringgo Village government for permission to carry out research in their agricultural land area.

References

[1] Peng, Z., He, Y., Guo, Z., et al., 2023. Species-specific arsenic species and health risk assessment in seaweeds from tropic coasts of South China Sea. Ecotoxicology and Environmental Safety. 267, 115634. DOI: https://doi.org/10.1016/j.ecoenv.2023.115634

[2] Mulya, S.P., Hudalah, D., 2024. Agricultural intensity for sustainable regional development: A case study in peri-urban areas of Karawang Regency, Indonesia. Regional Sustainability. 5(1), 100117. DOI: https://doi.org/10.1016/j.regsus.2024.100117

[3] Tiwari, P., Poudel, K.P., Yang, J., et al., 2023. Marginal agricultural land identification in the Lower Mississippi Alluvial Valley based on remote sensing and machine learning model. International Journal of Applied Earth Observation and Geoinformation. 125, 103568. DOI: https://doi.org/10.1016/j.jag.2023.103568

[4] Mosharaf, M.K., Gomes, R.L., Cook, S., et al., 2024. Wastewater reuse and pharmaceutical pollution in agriculture: Uptake, transport, accumulation and metabolism of pharmaceutical pollutants within plants. Chemosphere. 364, 143055. DOI: https://doi.org/10.1016/j.chemosphere.2024.143055

[5] Kane, J.L., Schartiger, R.G., Daniels, N.K., et al., 2023. Bioenergy crop Miscanthus x giganteus acts as an ecosystem engineer to increase bacterial diversity and soil organic matter on marginal land. Soil Biology and Biochemistry. 186, 109178. DOI: https://doi.org/10.1016/j.soilbio.2023.109178

[6] Saini, K., Singh, J., Malik, S., et al., 2024. Metal-Organic Frameworks: A promising solution for efficient removal of heavy metal ions and organic pollutants from industrial wastewater. Journal of Molecular Liquids. 399, 124365. DOI: https://doi.org/10.1016/j.molliq.2024.124365

[7] Zimmer, H., Tran, L.D., Dang, T.T., et al., 2022. Rehabilitating forest and marginal land using native species in mountainous northern Vietnam. Trees, Forests and People. 10, 100323. DOI: https://doi.org/10.1016/j.tfp.2022.100323

[8] Tan, Y., Chen, H., Xiao, W., et al., 2021. Influence of farmland marginalization in mountainous and hilly areas on land use changes at the county level. Science of The Total Environment. 794, 149576. DOI:

https://doi.org/10.1016/j.scitotenv.2021.149576

[9] Meehan, P., Burke, B., Doyle, D., et al., 2017. Exploring the potential of grass feedstock from marginal land in Ireland: Does marginal mean lower yield? Biomass and Bioenergy. 107, 361–369. DOI: https://doi.org/10.1016/j.biombioe.2017.10.014

[10] Roy, S.K., Alam, M.T., Mojumder, P., et al., 2024. Dynamic assessment and prediction of land use alterations influence on ecosystem service value: A pathway to environmental sustainability. Environmental and Sustainability Indicators. 21, 100319. DOI: https://doi.org/10.1016/j.indic.2023.100319

[11] Anda, M., Sukarman, S., Yatno, E., et al., 2024. Mapping the spatial distribution of pyrite and evaluating soil and water properties in idle swamp land: A strategy to promote sustainable paddy field establishment and prevent land degradation. CATENA. 241, 107985. DOI: https://doi.org/10.1016/j.catena.2024.107985

[12] Makungwe, M., Chabala, L.M., Van Dijk, M., et al., 2021. Assessing land suitability for rainfed paddy rice production in Zambia. Geoderma Regional. 27, e00438. DOI: https://doi.org/10.1016/j.geodrs.2021.e00438

[13] Omotayo, A. O., Omotayo, O. P., 2024. Potentials of microbe-plant assisted bioremediation in reclaiming heavy metal polluted soil environments for sustainable agriculture. Environmental and Sustainability Indicators. 22, 100396. DOI: https://doi.org/10.1016/j.indic.2024.100396

[14] Rampa, A., Lovo, S., 2023. Revisiting the effects of the Ethiopian land tenure reform using satellite data. A focus on agricultural productivity, climate change mitigation and adaptation. World Development. 171, 106364. DOI: https://doi.org/10.1016/j.worlddev.2023.106364

[15] APHA American Public Health Association, 2005. Standard Methods for the Examination of Water and Wastewater. Washington DC: APHA (American Public Health Association). 1288 p.

[16] Tan, K.H., 2005. Soil Sampling. Preparation, and Analysis. CRC Press. DOI: https://doi.org/10.1201/9781482274769

[17] Ma, Z., Song, X., Wan, R., et al., 2013. A modified water quality index for intensive shrimp ponds of Litopenaeus vannamei. Ecological Indicators. 24, 287–293. DOI: https://doi.org/10.1016/j.ecolind.2012.06.024

[18] Tukey, J.W., Mosteller, F., Hoaglin, D.C., 2000. Understanding Robust and Exploratory Data Analysis. New York: J. Wiley. 480 p.

[19] Kay, P., Blackwell, P.A., Boxall, A.B.A., 2005. Column studies to investigate the fate of veterinary antibiotics in clay soils following slurry application to agricultural land. Chemosphere. 60(4), 497–507. DOI: https://doi.org/10.1016/j.chemosphere.2005.01.028

[20] Di Loreto Di Raimo, L.A., Couto, E.G., Poppiel, R.R., et al., 2024. Sand subfractions by proximal and satellite sensing: Optimizing agricultural expansion in tropical sandy soils. CATENA. 234, 107604. DOI: https://doi.org/10.1016/j.catena.2023.107604

[21] Yu, Z., Zhang, F., Gao, C., et al., 2024. The potential for bioenergy generated on marginal land to offset agricultural greenhouse gas emissions in China. Renewable and Sustainable Energy Reviews. 189, 113924. DOI: https://doi.org/10.1016/j.rser.2023.113924

[22] Zhang, T., Li, Y., Wang, M., 2024. Remote sensing-based prediction of organic carbon in agricultural and natural soils influenced by salt and sand mining using machine learning. Journal of Environmental Management. 352, 120107. DOI: https://doi.org/10.1016/j.jenvman.2024.120107

[23] Islam, M.S., Nakagawa, K., Yu, Z.-Q., et al., 2023. Coprostanol adsorption behavior in agricultural soil, riverbed sediment, and sand. Journal of Environmental Chemical Engineering. 11(3), 110029. DOI: https://doi.org/10.1016/j.jece.2023.110029

[24] Ghaneei-Bafghi, M.-J., Feiznia, S., Mokhtari, A.R., et al., 2024. Agricultural soil contamination and degradation near a mining area in an arid region. Journal of Geochemical Exploration. 256, 107349. DOI: https://doi.org/10.1016/j.gexplo.2023.107349

[25] Sharofiddinov, H., Islam, M., Kotani, K., 2024. How does the number of water users in a land reform matter for water availability in agriculture? Agricultural Water Management. 293, 108677. DOI: https://doi.org/10.1016/j.agwat.2024.108677

[26] Ariadi, H., Fahrurrozi, A., Al Ramadhani, F.M., 2024. Outlook Silvofishery. Indramayu: Penerbit ADAB. 75 p.

[27] Ariadi, H., Azril, M., Mujtahidah, T., 2023. Water Quality Fluctuations in Shrimp Ponds During Dry and Rainy Seasons. Croatian Journal of Fisheries. 81(3), 127–137. DOI: https://doi.org/10.2478/cjf-2023-0014

[28] Sinha, E., Calvin, K.V., Kyle, P.G., et al., 2022. Implication of imposing fertilizer limitations on energy, agriculture, and land systems. Journal of Environmental Management. 305, 114391. DOI: https://doi.org/10.1016/j.jenvman.2021.114391

[29] Jamal Nasir, M., Farooq Haider, M., Ali, Z., et al., 2024. Evaluation of soil quality through simple additive soil quality index (SQI) of Tehsil Charsadda, Khyber Pakhtunkhwa, Pakistan. Journal of the Saudi Society of Agricultural Sciences. 23(1), 42–54. DOI: https://doi.org/10.1016/j.jssas.2023.09.001

[30] Wan, P., Zhou, Z., Yuan, Z., et al., 2024. Fungal community composition changes and reduced bacterial diversity drive improvements in the soil quality index during arable land restoration. Environmental Research. 244, 117931. DOI: https://doi.org/10.1016/j.envres.2023.117931

[31] Ariadi, H., Mujtahidah, T., Wafi, A., 2023. Implications of Good Aquaculture Practice (GAP) Application on Intensive Shrimp Ponds and The Effect on

Water Quality Parameter Compatibility. Journal of Aquaculture and Fish Health. 12(2), 259–268. DOI: https://doi.org/10.20473/jafh.v12i2.32371

[32] Ariadi, H., Fadjar, M., Mahmudi, M., 2019. Financial Feasibility Analysis of Shrimp Vannamei (Litopenaeus vannamei) Culture in Intensive Aquaculture System with Low Salinity. Economic and Social of Fisheries and Marine Journal. 007(01), 81–94. DOI: https://doi.org/10.21776/ub.ecsofim.2019.007.01.08

[33] Shanmugasundharam, A., Akhina, S.N., Adhithya, R.P., et al., 2023. Water quality index (WQI), multivariate statistical and GIS for assessment of surface water quality of Karamana river estuary, west coast of India. Total Environment Research Themes. 6, 100031. DOI: https://doi.org/10.1016/j.totert.2023.100031

[34] Seifi, A., Dehghani, M., Singh, V.P., 2020. Uncertainty analysis of water quality index (WQI) for groundwater quality evaluation: Application of Monte-Carlo method for weight allocation. Ecological Indicators. 117, 106653. DOI: https://doi.org/10.1016/j.ecolind.2020.106653

[35] Kan, J.-C., Ferreira, C.S.S., Destouni, G., et al., 2023. Predicting agricultural drought indicators: ML approaches across wide-ranging climate and land use conditions. Ecological Indicators. 154, 110524. DOI: https://doi.org/10.1016/j.ecolind.2023.110524

[36] Ariadi, H., Madusari, B.D., Mardhiyana, D., 2022. Analisis pengaruh daya dukung lingkungan budidaya terhadap laju pertumbuhan udang vaname (L. vannamei). EnviroScienteae. 18(1), 29. DOI: https://doi.org/10.20527/es.v18i1.12976

[37] Wang, C., Zhang, G., Zhu, P., et al., 2023. Spatial variation of soil functions affected by land use type and slope position in agricultural small watershed. CATENA. 225, 107029. DOI: https://doi.org/10.1016/j.catena.2023.107029

[38] Young, E.H., Unc, A., 2023. A review of nematodes as biological indicators of sustainable functioning for northern soils undergoing land-use conversion. Applied Soil Ecology. 183, 104762. DOI: https://doi.org/10.1016/j.apsoil.2022.104762

[39] Yang, H., Sheng, R., Zhang, Z., et al., 2016. Responses of nitrifying and denitrifying bacteria to flooding-drying cycles in flooded rice soil. Applied Soil Ecology. 103, 101–109. DOI: https://doi.org/10.1016/j.apsoil.2016.03.008

[40] Ariadi, H., Madusari, B.D., Mardhiyana, D., 2024. Dynamic Modelling Analysis on The Effectiveness of Coastal Land Resources for Aquaculture Activities Utilization. Jurnal Pengelolaan Sumberdaya Alam Dan Lingkungan (Journal of Natural Resources and Environmental Management). 14(1), 174–180. DOI: https://doi.org/10.29244/jpsl.14.1.174

[41] Madusari, B.D., Ariadi, H., Mardhiyana, D., 2023. The dynamics of Chlorella spp. abundance and its relationship with water quality parameters in intensive shrimp ponds. Biodiversitas Journal of Biological Diversity. 24(5), 2919–2926. DOI: https://doi.org/10.13057/biodiv/d240547

[42] Kalinski, J.-C.J., Noundou, X.S., Petras, D., et al., 2024. Urban and agricultural influences on the coastal dissolved organic matter pool in the Algoa Bay estuaries. Chemosphere. 355, 141782. DOI: https://doi.org/10.1016/j.chemosphere.2024.141782

[43] Stow, C.A., Rowe, M.D., Godwin, C.M., et al., 2023. Lake Erie hypoxia spatial and temporal dynamics present challenges for assessing progress toward water quality goals. Journal of Great Lakes Research. 49(5), 981–992. DOI: https://doi.org/10.1016/j.jglr.2023.02.008

[44] Wang, W., Yu, Z., Song, X., et al., 2022. Hypoxia formation in the East China Sea by decomposed organic matter in the Kuroshio Subsurface Water. Marine Pollution Bulletin. 177, 113486. DOI: https://doi.org/10.1016/j.marpolbul.2022.113486

[45] Garofalo, D.F.T., Novaes, R.M.L., Pazianotto, R.A.A., et al., 2022. Land-use change CO2 emissions associated with agricultural products at municipal level in Brazil. Journal of Cleaner Production. 364, 132549. DOI: https://doi.org/10.1016/j.jclepro.2022.132549

[46] Kamaludin, M., Narmaditya, B.S., Wibowo, A., et al., 2021. Agricultural land resource allocation to develop food crop commodities: lesson from Indonesia. Heliyon. 7(7), e07520. DOI: https://doi.org/10.1016/j.heliyon.2021.e07520

[47] Lisenbee, W., Saha, A., Mohammadpour, P., et al., 2024. Water quality impacts of recycling nutrients using organic fertilizers in circular agricultural scenarios. Agricultural Systems. 219, 104041. DOI: https://doi.org/10.1016/j.agsy.2024.104041

[48] Lessmann, M., Kanellopoulos, A., Kros, J., et al., 2024. A spatially explicit assessment on the carrying capacity of livestock under minimum feed imports and artificial fertilizer use in Dutch agriculture. Agricultural Systems. 220, 104092. DOI: https://doi.org/10.1016/j.agsy.2024.104092

[49] Yang, J., Ma, R., Yang, L., 2024. Spatio-temporal evolution and its policy influencing factors of agricultural land-use efficiency under carbon emission constraint in mainland China. Heliyon. 10(4), e25816. DOI: https://doi.org/10.1016/j.heliyon.2024.e25816

[50] Talbot, M.-H., Monfet, D., 2024. Development of a crop growth model for the energy analysis of controlled agriculture environment spaces. Biosystems Engineering. 238, 38–50. DOI: https://doi.org/10.1016/j.biosystemseng.2023.12.012

[51] Hamilton, A.N., Gibson, K.E., Amalaradjou, M.A., et al., 2023. Cultivating Food Safety Together: Insights About the Future of Produce Safety in the U.S. Controlled Environment Agriculture Sector.

Journal of Food Protection. 86(12), 100190. DOI: https://doi.org/10.1016/j.jfp.2023.100190

[52] Aditya, F., Gusmayanti, E., Sudrajat, J., 2021. Pengaruh Perubahan Curah Hujan terhadap Produktivitas Padi Sawah di Kalimantan Barat. Jurnal Ilmu Lingkungan. 19(2), 237–246. DOI: https://doi.org/10.14710/jil.19.2.237-246

[53] Birkhofer, K., Bird, T., Alfeus, M., et al., 2024. Smallholder agriculture in African dryland agroecosystems has limited impact on trophic group composition, but affects arthropod provision of ecosystem services. Agriculture, Ecosystems & Environment. 363, 108860. DOI: https://doi.org/10.1016/j.agee.2023.108860

[54] Torres-Bejarano, F., García-Gallego, J., Salcedo-Salgado, J., 2023. Numerical modeling of nutrient transport to assess the agricultural impact on the trophic state of reservoirs. International Soil and Water Conservation Research. 11(1), 197–212. DOI: https://doi.org/10.1016/j.iswcr.2022.06.002

[55] Solanki, M.K., Joshi, N.C., Singh, P.K., et al., 2024. From concept to reality: Transforming agriculture through innovative rhizosphere engineering for plant health and productivity. Microbiological Research. 279, 127553. DOI: https://doi.org/10.1016/j.micres.2023.127553