Medicon Agriculture & Environmental Sciences
Volume 9 Issue 2 August 2025
Article Type: Research Article
ISSN: 2972-2691

Monitoring Land use Change in Response to Temporal Salinity in the Mekong Delta

Nguyen Ngoc Mong Kha[1,2]* and Chau Minh Khoi[3]

[1]*PhD student at Can Tho University, 3/2 Street, Ninh Kieu Ward, Can Tho City, Vietnam*

[2]*Department of Science and Technology, An Giang Province, Vietnam*

[3]*College of Agriculture, Can Tho University, 3/2 Street, Ninh Kieu Ward, Can Tho City, Vietnam*

***Corresponding Author:** Nguyen Ngoc Mong Kha, College of Agriculture, Can Tho University, 3/2 Street, Ninh Kieu Ward, Can Tho City, Vietnam.

Received: July 19, 2025; **Published:** July 28, 2025

DOI: 10.55162/MCAES.09.259

Abstract

The main aim of this research was to evaluate the soil salinity variations in coastal regions of the Vietnamese Mekong Delta (VMD) over time and space. Soc Trang province was selected as the case study due to its unique geographical features, including a southeastern coastal zone and a river channel that runs along the northeastern edge of the province. The observation period focused on the dry seasons spanning the years 2020 to 2021. Soil samples were obtained monthly (during the dry seasons) from the upper 20 cm at over 1,000 locations and the electrical conductivity (EC1:5, dS/m) was measured using Conductivity Meter. Based on soil salinity levels, it suggests appropriate arrangements of upland crops that align with the specific characteristics of the soil. Furthermore, the study utilized soil salinity data to propose a sustainable cropping model designed to suit these conditions. The results showed that Soc Trang Province consistently experienced salinity intrusion during February and March annually. In March 2020, areas with high salinity levels were detected approximately 40 km from the nearest coastline, with this distance extending to nearly 55 km by March 2021. Subsequently, based on the spatial and temporal salinity intrusion maps, the study proposes crop conversion strategies in selected salt-affected areas to enhance adaptation to climate change. This study contributes to the understanding of climate change impacts and facilitates the management of agro-ecological landscapes in the region.

Keywords: soil salinity; crops; climate change; Soc Trang

Introduction

As the third-largest delta globally, the Mekong Delta (MD) is acknowledged for its role as an agricultural production region and biodiversity hotspot (Xiao et al., 2021) . Over the past few years, substantial changes in land use and land cover (LULC) in the MD have occurred, primarily due to the increasing impact of salinity intrusion and anthropogenic activities (Park et al., 2022). Salinity intrusion in the MD significantly obstructed agricultural practices by increasing soil salinity levels and changing the quality of irrigation water. This phenomenon posed a major challenge to crop cultivation, particularly rice, impacting yields and overall productivity (Le et al., 2018) and potentially requiring alternative crops for future cultivation (Kaveney et al., 2023). In parallel to the changing salinity regime has been substantial changes in spatial patterns of farming and water regime (Vu et al., 2022). Understanding the relationship between temporal salinity over time and spatial distribution of land use changes is crucial for effective land management. By monitoring salinity variations over time and how land use has changed with it, we can inform strategic decision-making for sustainable adaptation in vulnerable regions like the MD. This study aims to address the relationship between temporal salinity and land use changes in the MD, offering insights for sustainable development strategies. To achieve the above objective, the study focuses on two main components: (i) the spatial and temporal assessment of saltwater intrusion; and (ii) the proposal of feasible measures to respond to saltwater intrusion.

Materials and Methods

Soil samples were collected and analysed on a monthly basis in Soc Trang province, with the measured soil salinity (EC1:5) converted to electrical conductivity of the saturation extract (ECe). The classification of salinity levels followed the criteria outlined by Slavich and Petterson (1993), which categorizes the results into six distinct classes. Hexagonal binning was employed as a spatial aggregation method to transform point data into a continuous representation of soil salinity distribution. This technique offers advantages over traditional interpolation methods by reducing bias and providing a more accurate representation of spatial patterns (Weckmüller and Dunkel, 2023). The hexagonal bins served as spatial units with a size of 10 square kilometres, and salinity values from the surveyed samples within each bin were aggregated to create a continuous salinity map using ArcGIS Pro 3.3. This spatial representation allows for a comprehensive depiction of temporal changes in soil salinity, enabling a nuanced understanding of its variations across the study area.

To develop the LULC map, this study applied the Random Forest (Breiman, 2001) classifier to map land cover in the MD using Sentinel-1 and Sentinel-2 data. The process involved enhancing data quality through pre-processing and partitioning the ground truthed data into training and validation sets. Utilizing ground-truth data for training, the Random Forest algorithm has been shown to have good accuracy in classifying different land cover types, especially in capturing complicated landscape variations (Binh et al., 2021). This approach can effectively handle multi-spectral or hyperspectral data, making them valuable for tasks such as land cover classification, vegetation mapping, and change detection, contributing to the generation of accurate land cover maps essential for sustainable regional management. Change detection of LULC was performed through the overlay and post-classification comparison of the LULC maps across the different time periods. To enhance the clarity of our results, the change dynamics are visually presented in maps. Based on soil salinity levels, appropriate arrangements of upland crops that align with the specific characteristics of the soil were suggested. Furthermore, the study utilized soil salinity data to propose a sustainable cropping model designed to suit these conditions.

Results and Discussion

The spatial and temporal assessment of saltwater intrusion

The spatial representation revealed distinct patterns in salinity levels, with varying degrees observed across the surveyed points (Figure 1). Hotspots of elevated salinity were identified, suggesting localized areas of concern, with clear seasonal patterns showing elevated salinity across many farms in 2020. This seasonal pattern highlights the dynamic changes in salinity in space and time, emphasizing the need for ongoing monitoring and adaptive management strategies to address the evolving environmental conditions.

The LULC maps for the years 2015 through 2022, generated from Sentinel satellite imagery, are depicted in Figure 2. The classification result represents six primary categories of land use: (1) Paddy rice, (2) Orchard, (3) Water, (4) Settlement (or urban area), (5) Aquaculture, and (6) Forest. These categories serve as key indicators in the systematic analysis of land utilization patterns over the specified timeframe. It can be observed that LULC has changed spatially with particular changes evident in the decline in paddy rice areas, largely converted to aquaculture and orchard. While these patterns are generally consistent with other recent remote sensing research (Vu et al., 2022), it is still critical to develop the classification algorithm to address uncertainty in such a complex aquatic landscape as the MD.

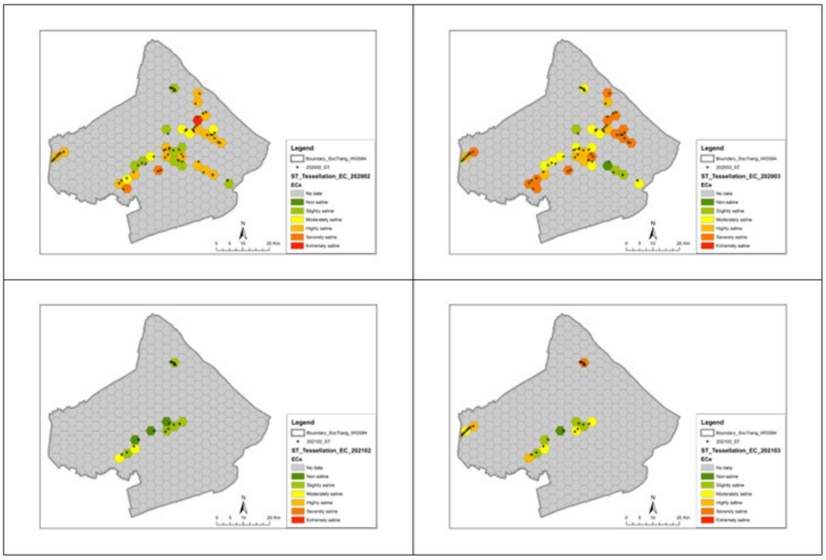

Figure 1: Spatial variation of soil salinity in Soc Trang province (a) February 2020, (b) February 2021, (c) March 2020 and (d) March 2021.

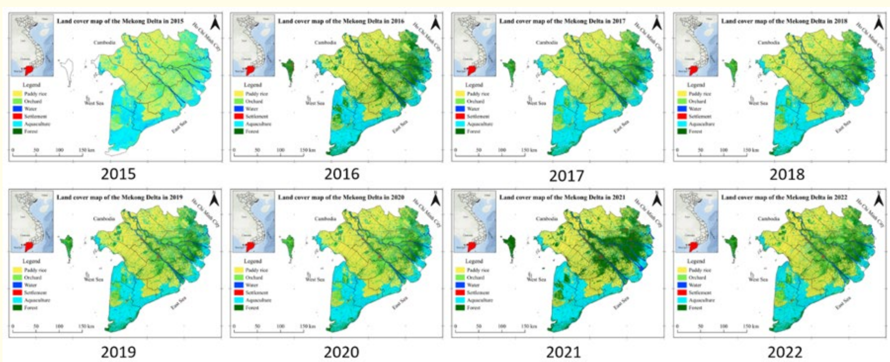

Figure 2: LULC classification maps of the MD in the year 2015-2022 based on Sentinel images.

The observed spatial variations in soil salinity over time with an evident increase compared to previous years, highlighted the dynamic nature of environmental factors influencing the study area. The elevation in salinity levels can be attributed to a variety of factors, encompassing changes in climate patterns, changes in land use practices, and the impact of natural processes in the MD (Kaveney et al., 2023; Ha et al., 2024).

The LULC maps indicate a comprehensive of land cover across a seven-year span, from 2015 to 2022, with six different classes. Notably, spatial analysis reveals dynamic changes in land cover, with coastal regions experiencing particularly pronounced changes with aquaculture conversion. These changes underscore the evolving nature of the landscape, influenced by various factors over time. The map serves as a valuable tool for understanding the spatial distribution of land cover classes and highlights the significance of coastal areas as dynamic zones where environmental factors, including potential salinity impacts, significantly contribute to the changes of land cover patterns.

The analysis of land use and land cover changes, particularly in the context of salinity intrusion, revealed a complex interplay between environmental factors and human activities. The observed alterations in land cover and land use patterns underscored the impact of salinity intrusion on the MD's landscape over the examined period. The results of this preliminary analysis showed how there has been substantial change in land use across the delta. This was consistent with other studies analysing this phenomenon (e.g. Vu et al., 2022). The next stage of this work will examine remotely sensed soil salinity data as a potential driver of the observed land use change (e.g. Nguyen et al., 2020). Such soil salinity data have come with its own limitations, however, a large scale spatial statistical study offered an avenue to understand the overlap between increasing salinity and land use change. The temporal evolution of soil salinity patterns, identified hotspots, and accuracy assessments of the remote sensing work provided valuable insights for sustainable land management and precision agriculture practices in regions affected by soil salinity.

Saltwater intrusion has driven significant land use changes in the Mekong Delta, combined with large-scale remote sensing analyses, offers critical insights for sustainable land management and precision agriculture in salinity-affected regions.

This knowledge contributes to more resilient and adaptive land use planning in response to changing environmental conditions. There are some studies that encompassed all types of land use to explore the LULC and its driving forces in the Mekong Delta from a holistic perspective (Liu et al., 2020; Ngo, Lechner and Vu, 2020). However, the lack of comprehensive knowledge about the interconnection between salinity intrusion and land use changes in the MD hinders the formulation of effective strategies for sustainable development. This information gap limits the implementation of targeted mitigation measures, impeding the region's ability to adapt to evolving environmental conditions and protect agricultural productivity.

Proposed Adaptation Solutions

Shifting crop patterns in salinity-affected zones

In non-saline areas (ECe < 2 dS/m), farmers can cultivate various food crops such as rice, maize, and sweet potato, as well as salt-sensitive vegetables including tomato, eggplant, and leafy greens. Fruit trees are also suitable for cultivation in these areas. In general, most crops can be grown in non-saline soils without significant limitations.

In slightly saline areas (ECe 2 - 4 dS/m), it is advisable to avoid salt-sensitive crops such as eggplant, orange, and pomelo. For moderately saline areas (ECe 4 - 8 dS/m), farmers should prioritize salt-tolerant crops such as betroot, corn, watermelon, peanut, rice, cucumber, yard-long bean, soybean, and guava, as these species have better adaptability to saline conditions.

In hightly saline zones (ECe 8 - 16 dS/m), farmers may consider converting to brackish water aquaculture during the dry season, combined with rotational cultivation of salt-tolerant crops during the wet season. In severely saline areas (ECe > 16 dS/m), the land is best suited exclusively for saline aquaculture and the cultivation of certain salt-adapted crops.

Transformation of livelihood strategies in salinity-affected areas

Figures 1 and 2 illustrate that the current land use maps overlaid with salinity boundaries in Soc Trang Province. Moderately affected areas such as Thanh Tri, My Tu, and Long Phu are primarily rice-cultivated zones with dissolved salt concentrations ranging from 2 to 4 dS/m. Although this salinity level may impact rice yields, rice crops can still tolerate and grow under such conditions; therefore, maintaining the rice cultivation model in these regions is recommended to ensure food security.

In salinity-affected areas such as My Xuyen, Tran De, Long Phu, and Cu Lao Dung, a rice - shrimp rotational farming system should be adopted - cultivating rice during the rainy season and farming shrimp during the dry season. For areas experiencing higher salinity, a complete shift to aquaculture may offer greater economic efficiency compared to traditional agricultural practices.

In severely salt-affected zones such as Vinh Chau, Tran De, and Cu Lao Dung, land use conversion toward aquaculture is strongly recommended.

The study proposes crop conversion strategies in selected salt-affected areas to enhance adaptation to climate change.

Conclusion

Saltwater intrusion has driven significant land use changes in the Mekong Delta, and that training farmers to monitor soil salinity, combined with large-scale remote sensing analyses, offers critical insights for sustainable land management and precision agriculture in salinity-affected regions.

Subsequently, based on the spatial and temporal salinity intrusion maps, the study proposes crop conversion strategies in selected salt-affected areas to enhance adaptation to climate change.

Acknowledgements

This study was funded by Australian Centre for International Agricultural Research (ACIAR), Project SLAM/2018/144. The authors thank Dr. Jason Condon at Charles Sturt University, Australia for giving opportunity to participate in the project; and Dr. Ben Stewart-Koster at Griffith University, Australia for scientific advices concerning the land use and land cover mapping methodology. We also acknowledge Department of Agriculture and Rural Development for helpful discussions on the management of salinity in Soc Trang Province, Vietnam.

References

1. Binh NA., et al. "Thirty-year dynamics of LULC at the dong thap muoi area, Southern Vietnam, using google earth engine". ISPRS International Journal of Geo-Information 10.4 (2021).
2. Breiman L. "Random Forests". Machine Learning 45 (2001): 5-32.
3. Ha T., et al. "Understanding factors influencing farmers ' crop choice and agricultural transformation in the Upper Vietnamese Mekong Delta". Agricultural Systems. Elsevier Ltd 216 (2024): 103899.
4. Kaveney B., et al. "Inland dry season saline intrusion in the Vietnamese Mekong River Delta is driving the identification and implementation of alternative crops to rice". Agricultural Systems. Elsevier Ltd 207 (2023): 103632.
5. Le TN., et al. "Interplay between land-use dynamics and changes in hydrological regime in the Vietnamese Mekong Delta". Land Use Policy 73 (2018): 269-280.
6. Liu S., et al. "Understanding Land use/Land cover dynamics and impacts of human activities in the Mekong Delta over the last 40 years". Global Ecology and Conservation. Elsevier Ltd 22 (2020): e00991.
7. Ngo KD, Lechner AM and Vu TT. "Land cover mapping of the Mekong Delta to support natural resource management with multi-temporal Sentinel-1A synthetic aperture radar imagery". Remote Sensing Applications: Society and Environment 17 (2020): 1-14.
8. Nguyen KA., et al. "Soil salinity assessment by using near-infrared channel and Vegetation Soil Salinity Index derived from Landsat 8 OLI data: a case study in the Tra Vinh Province, Mekong Delta, Vietnam". Progress in Earth and Planetary Science. Progress in Earth and Planetary Science 7.1 (2020): 1-16.
9. Park E., et al. "The worst 2020 saline water intrusion disaster of the past century in the Mekong Delta: Impacts, causes, and management implications". Ambio. Springer Netherlands 51.3 (2022): 691-699.

10. Vu HTD., et al. "Land use change in the Vietnamese Mekong Delta: New evidence from remote sensing". Science of the Total Environment. Elsevier B.V 813 (2022): 151918.
11. Weckmüller D and Dunkel A. "an Application-Oriented Implementation of Hexagonal on-the-Fly Binning Metrics for City-Scale Georeferenced Social Media Data". International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives 48.4/W7-2023 (2023) : 253-260.
12. Xiao H., et al. "Saltwater intrusion into groundwater systems in the Mekong Delta and links to global change". Advances in Climate Change Research. Elsevier Ltd 12.3 (2021): 342-352.

Volume 9 Issue 2 August 2025