Nugraheni Setyaningrum[1], Andie Setiyoko[2], Galih Prasetya Dinanta[3],
Dandy Aditya Novresiandi[4], Arief Darmawan[5], Edy Trihatmoko[6],
Joko Widodo[7], Budhi Gustiandi[8]

Synthetic Aperture Radar Technology for Policies Contributing to Natural Disaster Mitigation and Food Security Issues in Indonesia

Abstract: Natural disasters and food security challenges frequently impact many countries, including Indonesia. Over the past decade, the development of remote-sensing technology (particularly, synthetic aperture radar [SAR]) has garnered the attention of policymakers. Its ability to penetrate clouds and rain and data-acquisition techniques unaffected by time (day or night) provide advantages for describing the equatorial region. The application of SAR technology in Indonesia has progressed significantly. However, an important question has arisen: to what extent is the impact of using SAR data? Most SAR data in Indonesia is still limited to academic circles. To address this question comprehensively, this research examines the extent to which studies utilize SAR data – particularly, in global publications. The scope of this research was limited to articles published between 2013 and early 2025 that utilized SAR as the primary or secondary methods. The gap between the numerous studies on SAR technology and its significant impact on various government policies was quantitatively analyzed. In conclusion, this research underscored the need for a more nuanced approach toward integrating SAR technology into policymaking in Indonesia. This study serves as a critical reflection on the current state of SAR research in Indonesia, calling for a more concerted effort to bridge the gap between technical studies and actionable policy formulation.

Keywords: synthetic aperture radar, regulation, food security, natural disaster, policy

1   National Research and Innovation Agency, Research Center for Geoinformatics, Jakarta, Indonesia,
    email: nugr006@brin.go.id, https://orcid.org/0009-0009-4506-6664
2   National Research and Innovation Agency, Research Center for Geoinformatics, Jakarta, Indonesia,
    email: andi015@brin.go.id, https://orcid.org/0000-0001-9002-4716
3   National Research and Innovation Agency, Bureau of Organization and Human Resources, Jakarta,
    Indonesia, email: gali006@brin.go.id (corresponding author), https://orcid.org/0000-0002-9696-1943
4   National Research and Innovation Agency, Research Center for Geoinformatics, Jakarta, Indonesia,
    email: dand002@brin.go.id, https://orcid.org/0000-0002-4576-8078
5   National Research and Innovation Agency, Research Center for Climate and Atmosphere, Jakarta,
    Indonesia, email: arie012@brin.go.id, https://orcid.org/0000-0001-7849-2883
6   National Research and Innovation Agency, Research Center for Geoinformatics, Jakarta, Indonesia,
    email: edyt002@brin.go.id, https://orcid.org/0000-0003-1998-9851
7   National Research and Innovation Agency, Research Center for Geoinformatics, Jakarta, Indonesia,
    email: joko024@brin.go.id, https://orcid.org/0000-0002-0552-5100
8   National Research and Innovation Agency, Research Center for Geoinformatics, Jakarta, Indonesia,
    email: budh006@brin.go.id, https://orcid.org/0000-0002-1323-1903

1.   Introduction

Situated in tropical regions with abundant fertile soil and favorable climates, Indonesia has historically facilitated year-round farming. However, the landscape has undergone significant transformations over the past decade. The proliferation of residential housing and flats has encroached upon farmlands [1, 2], thus diminishing their productivity and triggering a concerning "domino effect" on the national food supply chain. This trend, coupled with extensive land conversion for palm oil plantations [3, 4], have exacerbated the challenges that are being faced by Indonesian agriculture. Compounding the issue is the apparent lack of government policies that support anti-deforestation initiatives. Instead, policies that favor political interests, industrial plantations, and profitable businesses have taken precedence [5, 6]. The existing literature documents the alarming deforestation rate in Indonesia, attributing it to factors such as residential growth and illegal logging [7–10].

National food security has become a critical issue in the face of threats to the agricultural sector (where remote-sensing technology plays a crucial role in monitoring and analysis). Advancements in technology in space-based applications such as remote sensing are essential in investigating the capacities of agricultural production in large areas and determining national production capacities. Referring to diverse remote-sensing approaches, synthetic aperture radar (SAR) devices are versatile in investigating land changes, ground deformations, vegetation distributions, and soil moisture; they feature resiliency against atmospheric disturbances and provide more-reliable results that are based on object polarimetry. SAR has its drawbacks, however – particularly, given its high resource requirements for processing.

This study addresses food security and disaster-related challenges in Indonesia, with a focus on SAR research and its practical policy applications. Through a comprehensive review and analysis of SAR-based research from 2013 through 2025, this study clarifies how SAR data can help with early crop-failure detection, the accurate mapping of changes in agricultural lands, and the quick evaluation of areas that are affected by disasters. Three main contributions are presented in this study: (1) demonstrating how SAR-derived indicators can assist the government in allocating food reserves and establishing early warning systems; (2) showcasing the effectiveness of SAR in enhancing disaster responses through the timely high-resolution mapping of damage assessment; and (3) evaluating the influence of SAR research on policy formulation within Indonesia. This study aims to provide a roadmap for leveraging SAR technology in order to support data- and evidence-based policy decisions that enhance Indonesia's resilience against food insecurity and natural disasters.

2.   Materials and Methods

2.1. Data Collection and Search Strategy

A comprehensive literature search was conducted across university journals from 2013 through April 2025, including publications from Cambridge and Oxford

university presses, as well as databases such as Scopus, Web of Science, Sherpa Romeo, and DOAJ. Publisher information is displayed in Table 1. Publisher and journal categorization were based on impact factor and popularity metrics, following established methodologies [11, 12] with modifications as shown in the table below. Fifteen publishers were selected based on publication frequency; however, not all contained articles on (SAR applications in Indonesia (checkmarks indicate presence, dashes indicate absence).

Table 1. Fifteen well-known publishers were selected based on modifications that were made to previous study

No.	Publisher name	SAR	Case study in Indonesia
1	Springer	√	√
2	Taylor & Francis	√	√
3	Elsevier	√	√
4	Nature	√	√
5	Wiley	√	√
6	SAGE	√	–
7	Emerald	√	–
8	De Gruyter	√	–
9	Oxford University Press	√	√
10	Cambridge University Press	√	–
11	MDPI	√	√
12	IEEE	√	√
13	Hindawi	√	√
14	Frontiers	√	–
15	World Scientific	√	–

The review focused on studies tackling Indonesia's unique environmental and policy challenges where SARs have become the main method. Two main themes have emerged: (1) SAR in food security; and (2) SAR in natural hazards. To ensure rigor, only peer-reviewed articles from high-impact journals were included. Only those articles that used SAR as a primary or supplementary method were considered, followed by Indonesia as a primary or partial case study area. The authors' affiliations with Indonesian institutions were not mandatory

Boolean operators with the keywords "SAR" OR "synthetic aperture radar" and "food security" OR "natural hazard*" were used to create a methodical search protocol that curated a robust data set. The iterative refinement process eliminated non-empirical publications (e.g., editorials, errata, and retracted articles) and preferred original peer-reviewed research papers that were written in English because of their thorough methodological frameworks. This mitigated biases from non-reviewed sources while ensuring reproducibility. Only articles that were published from 2013 through 2025 were selected: for agricultural topics – articles that addressed food security (monitoring paddy, sorghum, or wheat); and for disaster topics – discussions of Indonesian disaster events using SAR. Articles that did not meet these criteria were excluded. The quarry resulted in 243 articles that met the criteria.

Figure 1 illustrates the analytical workflow, emphasizing the query formulation, database interrogation, and data triage. The Boolean search identified 243 peer-reviewed articles from multidisciplinary databases (e.g., Elsevier, Springer, and IEEE) that were classified as food security ($n = 26$) and natural hazard ($n = 217$) with diverse publishers. The screening process, such as the exclusion criteria (e.g., non-peer-reviewed sources) and distribution across thematic domains, is demonstrated in the figure below.
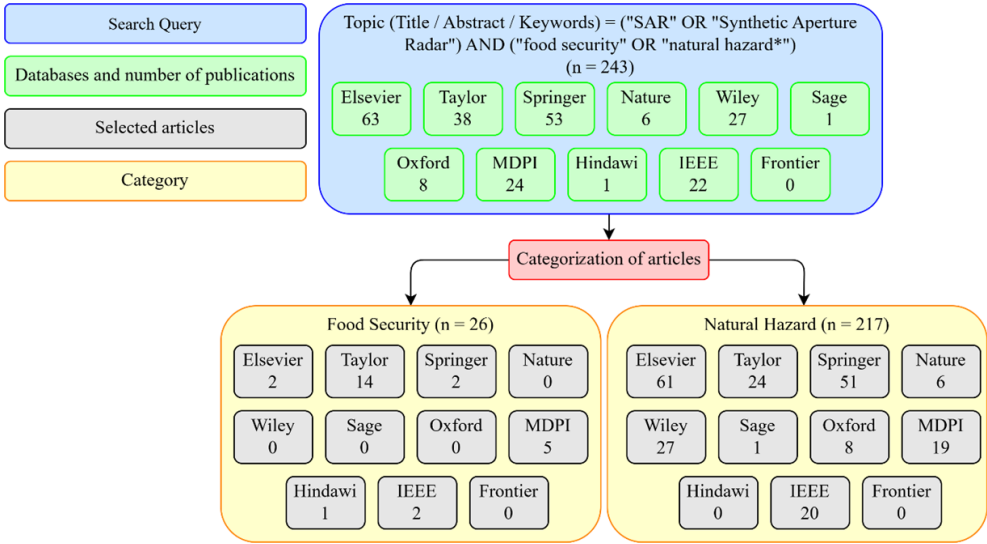

Fig. 1. Workflow of search strategy, database selection, and article categorization for SAR applications in food security and natural hazard research

2.2. Data Processing Procedures

In addition to the initial broad categorization, the collected articles underwent a granular grouping based on the specific objects that were addressed by each author, including the detections of farming products, land-use changes, and natural disaster

occurrences. For food security, the articles were sub-classified into food plantations (e.g., paddy, maize, sorghum, wheat) and industrial plantations (e.g., palm oil, pulp, rubber). For natural hazards, the articles were grouped into subtopics such as geothermal detection, landslides, volcanic activity, mining, deforestation, landscape change, climate change, and drought.

Bibliometric Analysis and Visualization

To conduct a comprehensive bibliometric analysis and visualize the research patterns, both Microsoft Excel and VOSviewer (https://www.vosviewer.com/) were utilized. Excel served as the primary tool for the initial data organization, cleaning, quantitative calculations, and generations of certain descriptive graphical representations of the data set. VOSviewer was specifically employed for constructing complex collaborative networks and performing keyword co-occurrence analyses, thus providing in-depth insights into global research partnerships and thematic trends.

Statistical Analysis

The statistical model was essential for analyzing the correlation between the intensity of the published journals regarding significant events or hazards during a year and the extent to which the related research contributed to policies and government regulations. While statistical methods are effective across various scenarios and case studies, it is important to note that such models cannot fully capture the complexities that are introduced by unpredictable psychological and political factors.

In this study, Poisson regression was employed as the best-fit method for analyzing the relationship between the SAR-related research output and the frequency of the published articles. The regression analysis model (RAM) is based on Poisson regression, which is well-suited for ungrouped, discrete, and non-negative data, and it accommodates rate-based patterns such as annual publication counts from 2013 through early 2025. RAM also analyzes temporal dependencies and avoids bias from categorizing distributed data with different variables (such as SAR in food security versus natural hazards) and their associations with major events. The Poisson regression can be expressed as follows:

$$P(Y = y \,|\, \lambda) = \frac{e^{-\lambda}\lambda^{y}}{y!} \tag{1}$$

The Poisson distribution applies to discrete non-negative integers ($y = 0, 1, 2, 3,...$). The distribution is characterized by a single parameter λ, which represents the mean rate of event occurrence. With the Poisson distribution, high counts are assumed to be rare (concerning the value of λ). The mean λ is linked to the predictors in a log function (as is expressed in the following equations:

$$\log(\lambda) = A + \beta_1 X_1 + \beta_2 X_2 + \dots \tag{2}$$

$$\log(\lambda) = f(y \,|\, \lambda) \tag{3}$$

In our analysis, the number of published articles was modeled as a function of the year and the dominant disaster type:

$$Number\ published\ articles \sim Year + Dominant\ disaster \tag{4}$$

Variables such as famine and national market peak demand for agricultural products were excluded, as they are less detectable.

3. Results and Discussion

The thematic distribution of the publications that were analyzed in this study adopted the Web of Science (WoS) classification framework, encompassing 15 subject areas for food security research (Fig. 2) and 40 for natural hazard studies (Fig. 3). Journal editorial boards assign articles to these categories; this often results in interdisciplinary overlaps where a single publication may span multiple domains [13].
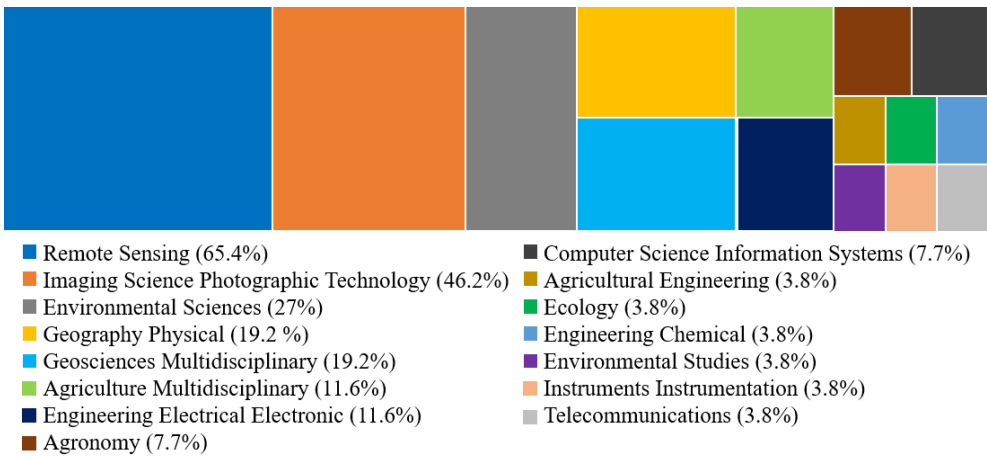

- Remote Sensing (65.4%)
- Imaging Science Photographic Technology (46.2%)
- Environmental Sciences (27%)
- Geography Physical (19.2 %)
- Geosciences Multidisciplinary (19.2%)
- Agriculture Multidisciplinary (11.6%)
- Engineering Electrical Electronic (11.6%)
- Agronomy (7.7%)
- Computer Science Information Systems (7.7%)
- Agricultural Engineering (3.8%)
- Ecology (3.8%)
- Engineering Chemical (3.8%)
- Environmental Studies (3.8%)
- Instruments Instrumentation (3.8%)
- Telecommunications (3.8%)

Fig. 2. Subject area distribution of SAR applications
in Indonesian food security research (2013–2025) as categorized by Web of Science;
remote sensing highlights SAR's role in crop monitoring and cloud penetration

Remote Sensing dominated both themes, accounting for 65.4% of food security publications and 34.1% of natural hazard studies. However, its broad scope (ranging from SAR data-processing techniques to environmental monitoring) underscored its methodological heterogeneity. For natural hazards, the contributions in *Geosciences Multidisciplinary* (33.2%) and *Imaging Science & Photographic Technology* (23%) further highlighted SAR's versatility in addressing geophysical risks such as earthquakes and floods. Figures 2 and 3 illustrate the diversity of the subjects, thus demonstrating the inherently multidisciplinary nature of SAR applications. For instance, food security research integrates *Agriculture Multidisciplinary* (11.6%) with *Engineering Electrical Electronic* (11.6%), while natural hazard studies bridge *Meteorology Atmospheric Sciences* (7.8%) and *Computer Science Interdisciplinary Applications* (1.4%).
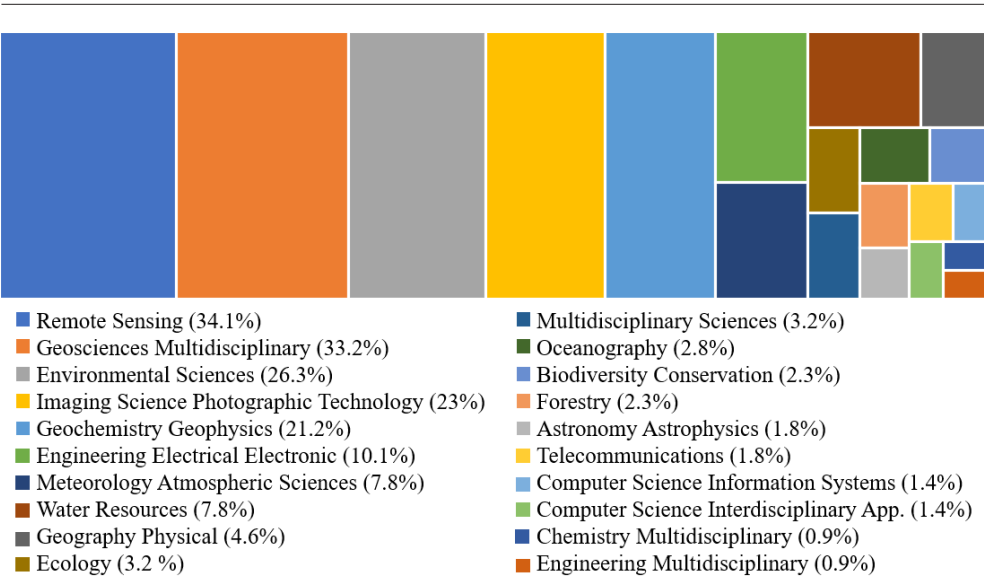
- Remote Sensing (34.1%)
- Geosciences Multidisciplinary (33.2%)
- Environmental Sciences (26.3%)
- Imaging Science Photographic Technology (23%)
- Geochemistry Geophysics (21.2%)
- Engineering Electrical Electronic (10.1%)
- Meteorology Atmospheric Sciences (7.8%)
- Water Resources (7.8%)
- Geography Physical (4.6%)
- Ecology (3.2 %)
- Multidisciplinary Sciences (3.2%)
- Oceanography (2.8%)
- Biodiversity Conservation (2.3%)
- Forestry (2.3%)
- Astronomy Astrophysics (1.8%)
- Telecommunications (1.8%)
- Computer Science Information Systems (1.4%)
- Computer Science Interdisciplinary App. (1.4%)
- Chemistry Multidisciplinary (0.9%)
- Engineering Multidisciplinary (0.9%)

Fig. 3. Top-20 subject areas for SAR-driven natural hazard studies in Indonesia (emphasizing geophysical and interdisciplinary methodologies)

Figure 4 illustrates a comparison of food security and natural hazard topics from 2013 through 2025. It indicates a significant imbalance, with 88% of the studies concentrating on natural hazards and only 12% focusing on food security.
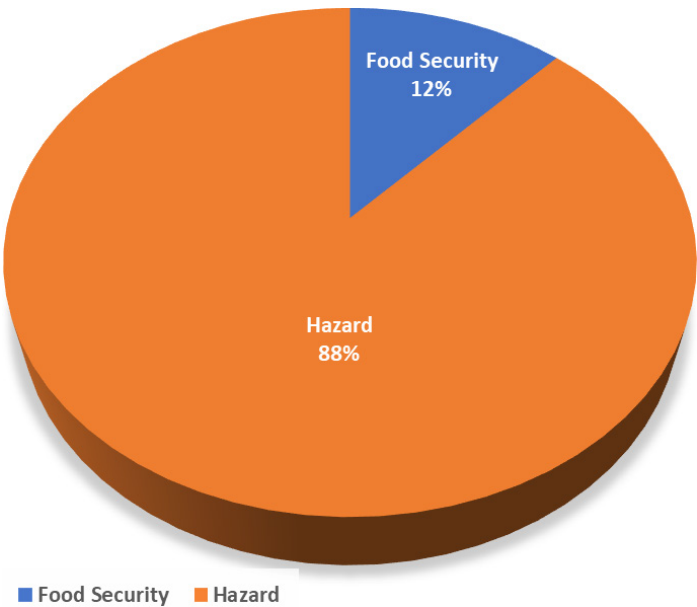

Fig. 4. Comparison between food security issues and disaster topics in Indonesia

3.1. SAR Articles With Food Security Themes

Food security is a popular topic among scientists; it drives much of the research on novel methods for predicting food production and storage based on the function of crop-area measurements. One of the attractive technologies for monitoring land use and cultivated areas is SAR, which enables planners to accurately calculate food volumetrics by using satellite data. Nowadays, the integration of machine learning with SAR analysis has further improved the detection and mapping of crop areas. For example, previous studies have successfully used SAR data to estimate the distribution of paddy and wheat fields [14, 15]

In academic research, keywords play a crucial role in reflecting thematic focuses, methodological trends, and emerging priorities [16]. A co-occurrence analysis of keywords from food security studies (specifically, those appearing at least twice) identified 14 key terms connected by 27 co-occurrence linkages (Fig. 5). These terms were then grouped into 5 thematic clusters. Excluding the term "synthetic aperture radar (SAR)" itself, the most dominant keywords were random forest, classification, data fusion, and deforestation. Additionally, the emergence of "agricultural insurance" as a key theme showed how SAR-based yield predictions were increasingly linked to risk management strategies. The frequent appearance of "deforestation" also underscored its dual significance: it is both a driver of food insecurity through land degradation and a focus for SAR-monitoring efforts.
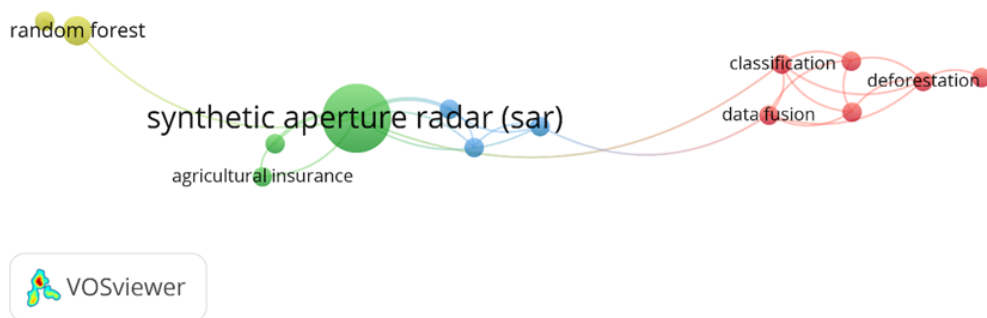

Fig. 5. Keywords that were covered by studies that focused on SAR data applications in food security research in Indonesia

Industrial plantations for products like rubber, pulpwood, and palm oil attract farmers when market prices rise. Rapid mapping for estimating the shifts from food to industrial plants can be achieved by using ALOS-PALSAR (as was shown by [17]). This phenomenon affects local communities, impacting not only economic factors but also biomass production and carbon stores [18]. While SAR is not the only method for food sustainability (as was noted by [19]), our study focused on the relevance of remote sensing in combination with rapid mapping, robust data sets, and reduced manpower. In-person surveys or aerial investigations cannot

surpass these advantages; nevertheless, they deliver superior data resolution and accuracy [20]. Radar data for SAR processing (whether for interferometry or time series analysis) consists of electromagnetic scattering-response information; when combined with other instruments such as NIR-green-blue (NGB) cameras, it accelerates the investigation process and reveals polarization values; this was demonstrated by Letsoin et al. [21] in their publication, where they identified the growth phases of food plants (such as paddy and maize) in Papua, Indonesia. This research led to the development of promising monitoring techniques.

The growing body of research on SAR applications for food security is also reflected in the pattern of scientific publications. Figure 6 presents the distribution of articles on this topic across various publishers. As is shown in the chart, Taylor & Francis published the most significant proportion of these studies (47%), followed by MDPI (17%), Elsevier and Springer (each 13%), IEEE (7%), and Hindawi (3%). Notably, major publishers such as Nature, Oxford University Press, and Wiley did not contribute articles on food security issues in the analyzed data set. This distribution suggested that research on SAR applications in food security was primarily disseminated through specialized journals with a focus on remote sensing, engineering, and environmental science rather than through general science outlets.
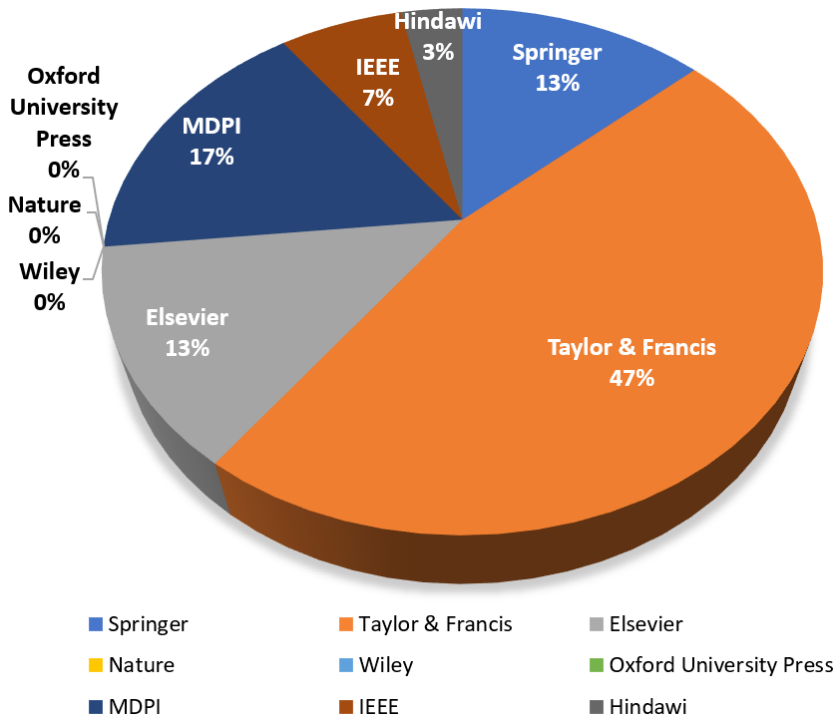

Fig. 6. Comparison of food security-related articles that were published by different publishers in Indonesia (2013–2025)

3.2. SAR Articles with Disaster Themes

Disaster themes in Indonesia attract more overseas researchers than food security topics (with some lacking local affiliations); the country's complex geology and extended coastline tend to draw global scientists. We compiled data from articles on disaster detection and prediction, including geothermal detection (SAR) [22], landslide detection [23], volcanic activity [24], mining [25], deforestation [26], landscape changes [27], climate [28], and drought [29]. Most hazard-related articles appeared after disasters like earthquakes. The notable earthquake in Palu, Sulawesi, garnered global interest, with many researchers using SAR and seismic monitoring to assess its damage levels [30, 31] and analyze its side effects (e.g., tsunamis and ruptures) [32, 33]. Some preferred SAR for its broader mapping capabilities, thus enabling comparisons of disaster-impacted areas based on distinct features (similar to other studies on land deformation [34]) or burned areas from satellite data [35].

A keyword co-occurrence analysis of natural hazard research identified 98 keywords with 552 linkages that were organized into 12 thematic clusters (Fig. 7).
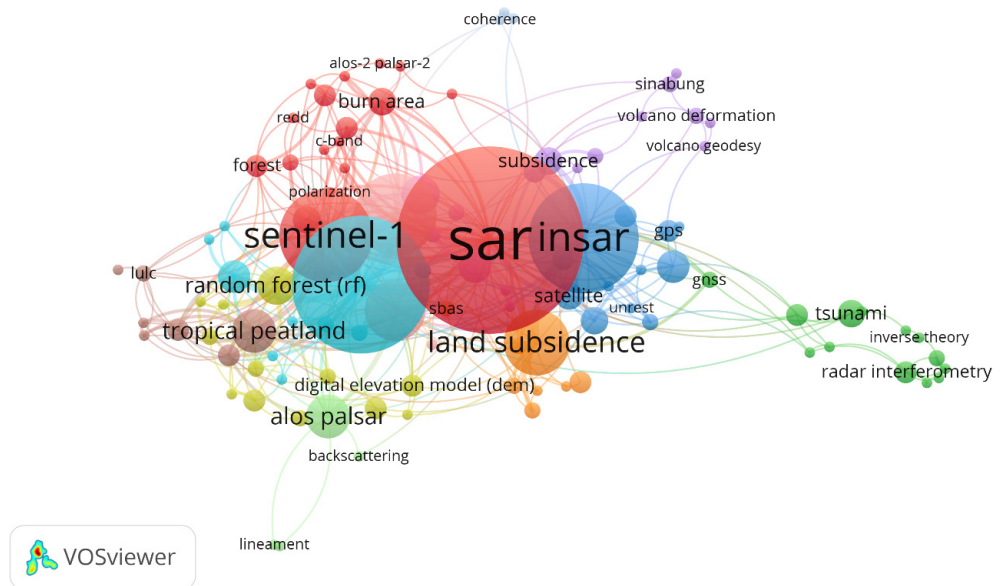

Fig. 7. Keywords that were covered by studies that focused on SAR data applications in natural hazard research in Indonesia region

Common keywords beyond SAR included Sentinel-1, ALOS PALSAR, land subsidence, tropical peatland, and random forest (thus, highlighting SAR's versatility). Sentinel-1 led the tectonic and flood studies due to its free high-temporal-resolution

data, while ALOS PALSAR was vital for monitoring peatland subsidence in Indonesia's fire-prone areas. The node proximity chart in Figure 7 indicates conceptual affinity, though the keywords may have extended outside their primary clusters; for instance, random forest is near both agricultural and hazard clusters, thus highlighting its relevance across multiple fields.

Despite the breadth of topics, most SAR-based disaster research in Indonesia remained focused on specific regions or events, such as certain earthquake events (Palu, Lombok, etc.) [31, 36], volcanic eruptions (Merapi, Kelud, etc.) [24, 37], or land subsidence (Jakarta, Semarang, etc.) [38, 39]. No comprehensive investigation has been conducted to assess the full impact of these events nationwide. Some articles also used SAR for other investigations, such as solitary waves [40] and coastline monitoring [41]; these were helpful for initiating mitigation actions and the early warning system (EWS) [42]. Time-series interferometry SAR (InSAR) and differential interferometry SAR (DInSAR) are prominent techniques that are used by researchers who focus on disasters via SAR. Further reading about how both methods work can be found in the literature [43–46].

A significant gap existed in SAR article coverage, with case studies mainly targeting Java and Sumatra (and a few in eastern Indonesia). Many articles offer limited recommendations for local governments, focusing instead on analytical findings. Some SAR research has enhanced radar performance but neglected its impact on institutions, governments, and communities. The journals covered similar topics, such as the Palu earthquake, deforestation, and the Mount Merapi eruptions [47, 48]. Disaster-related articles increased after events such as the Palu earthquake or Riau smoke hazard; this was especially notably one year later. In 2015, a large forest fire led to at least 20 SAR publications on fire hazards (with half of them related to smoke). In 2019, the Palu earthquake prompted research on SAR applications for post-hazard detection. From 2020 through 2022, flooding and volcanic eruptions were prevalent in SAR publications. Table 2 summarizes the dominant natural disasters in Indonesia from 2013 through 2025.

Table 2. Prevalence of natural disaster categories in Indonesia by year (2013–2025)

Year	Dominant Disaster
2013	Flooding
2014	Volcanic Eruption
2015	Smoke Hazard (Forest Fire)
2016	Earthquake
2017	Flooding and Landslide

Table 2. cont

Year	Dominant Disaster
2018	Earthquake
2019	Earthquake and Smoke Hazard
2020	Flooding
2021	Volcanic Eruption
2022	Earthquake
2023	Flooding
2024	Flooding
2025	Flooding

The trends in SAR article publications on natural disasters and their relationships to major events are illustrated in Figure 8; each disaster event appeared to act as a catalyst for new research, serving as the "main course" for potential authors. However, this event-driven research model can be considered to be unsustainable, as periods of relative calm lead to lacks of ongoing discussions and diminished stakeholder engagement. Without sustained studies on mitigation and preparedness, policymakers have a limited foundation on which to base their incorporation of scientific research into legislative processes.
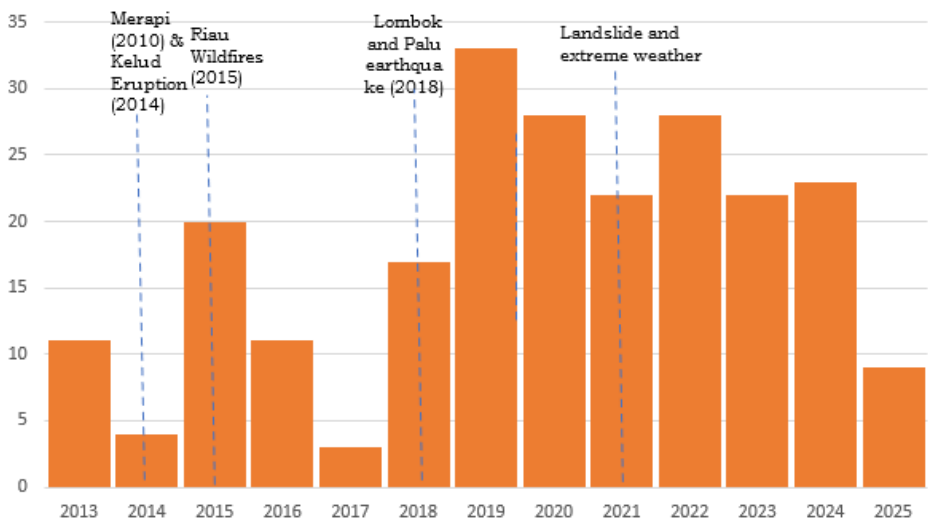

Fig. 8. Trends in SAR article publications on natural disasters
in Indonesia (2013–2025) and their relationships to major disasters

The total number of SAR publications on natural disasters over the last decade have shown increases in the numbers of articles after major events. Figure 9 reveals the fact that authors preferred to submit their works to Elsevier and Springer, while fewer articles appeared in Hindawi. This may have been the result of Hindawi's gold-access model, which is unlike the hybrid subscriptions that are offered by Elsevier and Springer; this could have deterred those authors who lacked sufficient research funding.
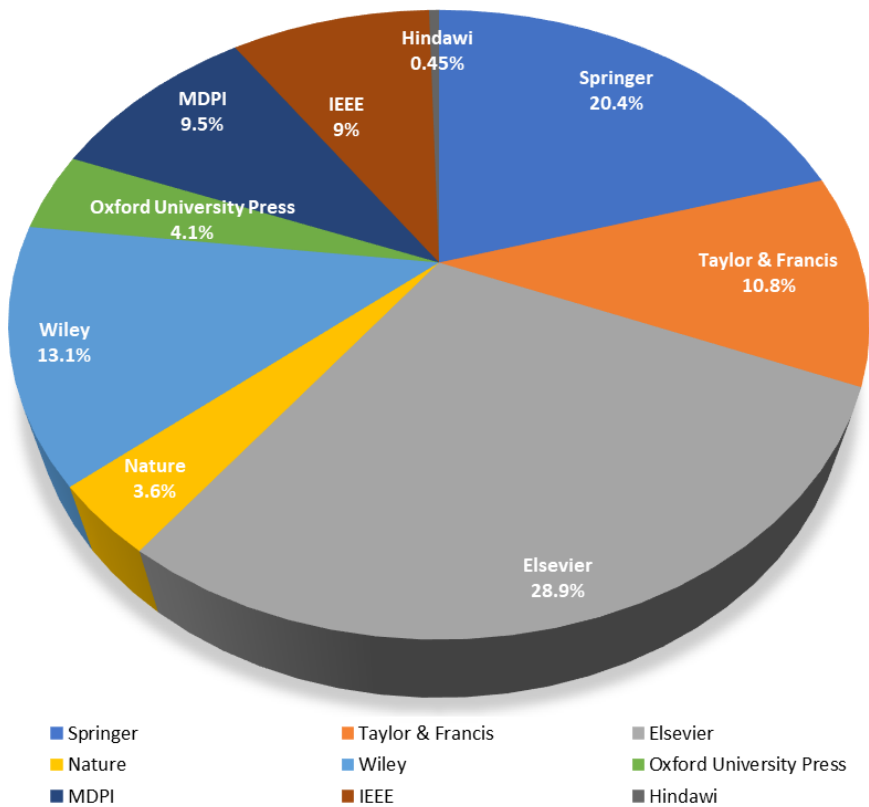
Fig. 9. Total SAR publications on natural disasters in last decade show increases in articles following major events

3.3. Distribution of Articles (Based on Case Study and Publication Years)

The investigation continued further to scientific research (and to those regulations where both should be implemented in the same direction) by taking the timelines for the issuance of regulatory policies relative to prior major events into account. Figure 10 illustrates the distribution of the articles by province.
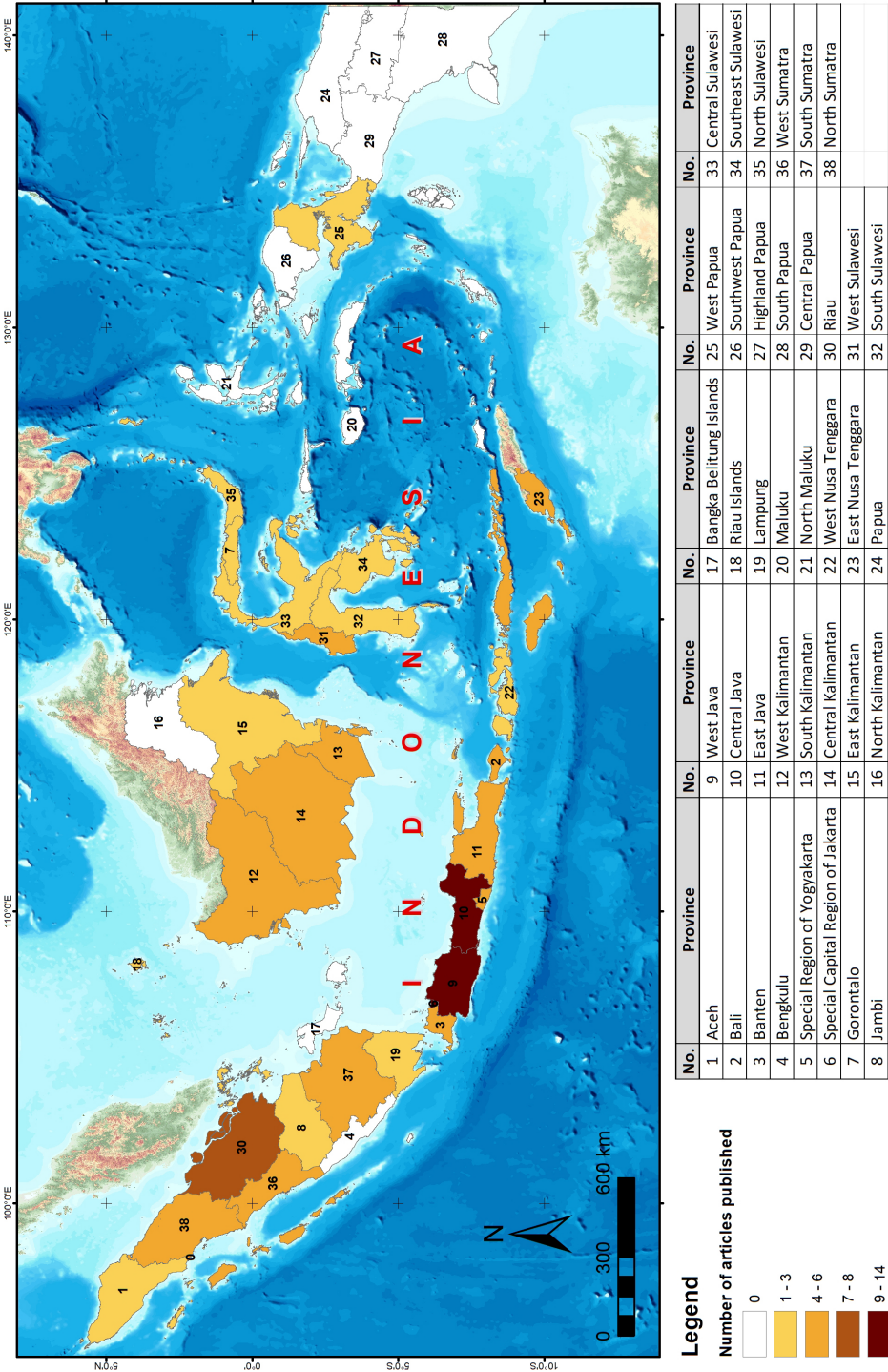
No.	Province	No.	Province	No.	Province	No.	Province	No.	Province
1	Aceh	9	West Java	17	Bangka Belitung Islands	25	West Papua	33	Central Sulawesi
2	Bali	10	Central Java	18	Riau Islands	26	Southwest Papua	34	Southeast Sulawesi
3	Banten	11	East Java	19	Lampung	27	Highland Papua	35	North Sulawesi
4	Bengkulu	12	West Kalimantan	20	Maluku	28	South Papua	36	West Sumatra
5	Special Region of Yogyakarta	13	South Kalimantan	21	North Maluku	29	Central Papua	37	South Sumatra
6	Special Capital Region of Jakarta	14	Central Kalimantan	22	West Nusa Tenggara	30	Riau	38	North Sumatra
7	Gorontalo	15	East Kalimantan	23	East Nusa Tenggara	31	West Sulawesi		
8	Jambi	16	North Kalimantan	24	Papua	32	South Sulawesi		

Fig. 10. Map showing article locations from Indonesia case study; not all are plotted due to unspecified provinces

According to the statistical distribution of all of the SAR articles that were obtained for food security and natural disaster themes, Elsevier, Springer, and Taylor & Francis were popular destinations for submitting research works, while MDPI and IEEE were considered to be second-tier publishers due to their article-processing charges (APCs) (Fig. 11).
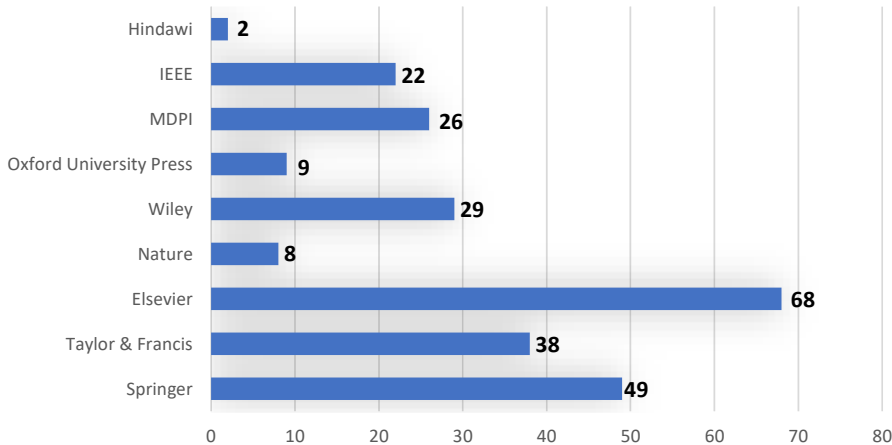

Fig. 11. This study assessed distribution of SAR articles with case studies in Indonesia on food security and disasters

3.4. Regulations Related to Food Security and Natural Disaster Mitigation

This study systematically selected key regulations based on their legal levels and years of enactment; these are detailed in Appendix: Table A1 (food security and industrial plantation) and Table A2 (natural disaster). We sought to link these regulations to SAR-related scientific papers that were published in the year before each regulation's adoption, thus observing the typical lag between research projects and policy development in Indonesia [49].

Regulations on food security in Indonesia began with Law No. 18/2012, which established the fundamental right to food and emphasized sovereignty, sustainability, and equity. This was supported by Omnibus Law No. 11/2020, which addressed agricultural-land protection and food-reserve adequacy; this balanced production and imports while safeguarding farmers' interests. Government regulations No. 17/2015 and No. 86/2019 detailed food reserves, nutrition, and safety standards. Presidential regulations such as No. 83/2017 and No. 66/2021 outlined national strategies and established food-management agencies, while ministerial regulations like the Ministry of Agriculture Regulation No. 38/2018 specified rice-reserve management. Law No. 18/2004 and its subsequent revisions governed sustainable practices and environmental protection on plantations.

The disaster laws in Indonesia have not been amended as frequently as food security laws have despite the increasing numbers of disaster-related articles that have been published throughout our study's timeframe. Based on an investigation of this study, disaster-management legislation in Indonesia was initiated in 2007 with Regulation No. 24/2007 (which is still in force today), followed by Regulation No. 21/2008; these were primarily issued to establish the National Agency for Disaster Management (BNPB) as the coordinating agency for disaster management.

Researchers agree that SAR can investigate land use and change [50–53] (among many other applications). A critical question arises: are stakeholders and policymakers considering this research? Effective regulations should be informed by scientific studies; however, discussions suggest policymakers may not emphasize relevant research results. This is evident in the lack of scientific studies that have been referenced in draft regulations. The state of the art of scientific studies is not being conveyed; the regulating parties rely solely on national needs, society pressures, and existing regulations. This places complex issues like food security and disaster management at risk of being addressed through less effective, non–evidence-based policies.

Therefore, comprehensive studies on how the government can better leverage SAR research for more-effective regulations is remains arguable. It is imperative to establish improved communications among researchers, stakeholders, and policymakers. Since the majority of SAR research in Indonesia has concentrated on technical monitoring rather than assisting legislative processes, an integrative approach has been mainly disregarded; this has left a gap in the possibility of evidence-based policymaking. Figure 12 illustrates this cycle, where disasters prompt research, research informs regulation, and regulation governs mitigation actions and stakeholder responsibilities in the events of disasters.
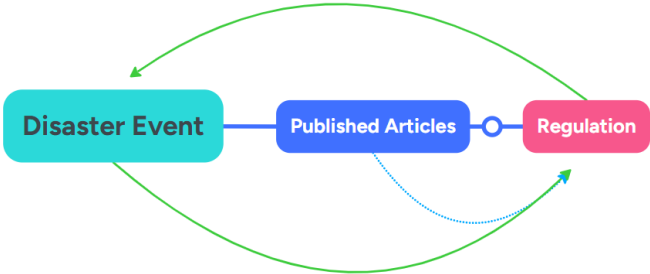

Fig. 12. Connections among events, articles, and regulations in one circle policy; disasters prompt research, which shapes regulation, guiding mitigation actions and stakeholders' responsibilities during disasters

3.5. Study Assessment

The summaries of the two clusters (natural disaster and food security) in Table 3 illustrate their correlation. The relationship between disaster events and SAR research output was measured with Poisson regression (Table 3). Key findings

indicated that earthquakes and smoke hazards (coefficient = 0.56, p = 0.01, z = 2.56) were the strongest predictors of increased numbers of publications, thus reflecting the heightened research activities following major events (such as the 2018 Palu earthquake and the 2015 haze crisis). Conversely, flooding and landslides (coefficient = −1.7, p = 0.004, z = −2.86) showed a significant negative correlation; this was likely due to their localized natures, which may have reduced their perceived novelty. Meanwhile, volcanic eruptions and smoke hazards (forest fires) had weaker correlations (p > 0.2), thus suggesting uneven prioritization despite their frequencies and societal impacts. These results highlighted the publication bias toward acute disasters over chronic hazards, thus pointing to gaps in sustained scientific engagement with Indonesia's diverse risk landscape.

Table 3. Poisson regression results correlating disaster types
with SAR publication trends (2013–2025)

Predictor	Coefficient	Std. error	p-value	z-value
Dominant disaster: earthquake and smoke hazards	0.56	0.22	0.01	2.56
Dominant disaster: flooding	0.19	0.18	0.298	1.04
Dominant disaster: flooding and landslides	1.7	0.6	0.004	2.86
Dominant disaster: smoke hazards (forest fires)	0.34	0.28	0.223	1.22
Dominant disaster: volcanic eruptions	0.3	0.24	0.215	1.24

These results (visualized in Figure 13) confirmed that disaster types and temporal contexts significantly influenced publication volumes. Often attracting international attention, earthquakes and transboundary haze events drive surges in SAR studies, whereas chronic hazards like flooding receive less sustained scholarly focus.

Whether technical or regulatory, all research projects are based on the fundamental tenets of novelty and urgency. Notably, SAR technology in remote sensing plays a pivotal role in discerning intricate details that are related to land-use and land-cover changes. This study adopted the concept of timelines and disaster events as the bases for estimating the formulations of government regulations. As previously mentioned, it makes intuitive sense that legislation would take journal reviews that were published no more than a year prior into account; therefore, those journals that were released during the same year as the regulations were excluded. Furthermore, each year witnessed an increasing number of publications on SAR with natural disaster as the primary theme (in contrast to the food security theme). Surprisingly, the regulations on food security underwent frequent updates or additions almost every year, suggesting the government's heightened interest in future research about food security rather than natural disaster themes. Figure 13 denotes the changes of regulations from 2013 through 2025 in conjunction with the numbers of SAR articles in food security and natural disaster themes.
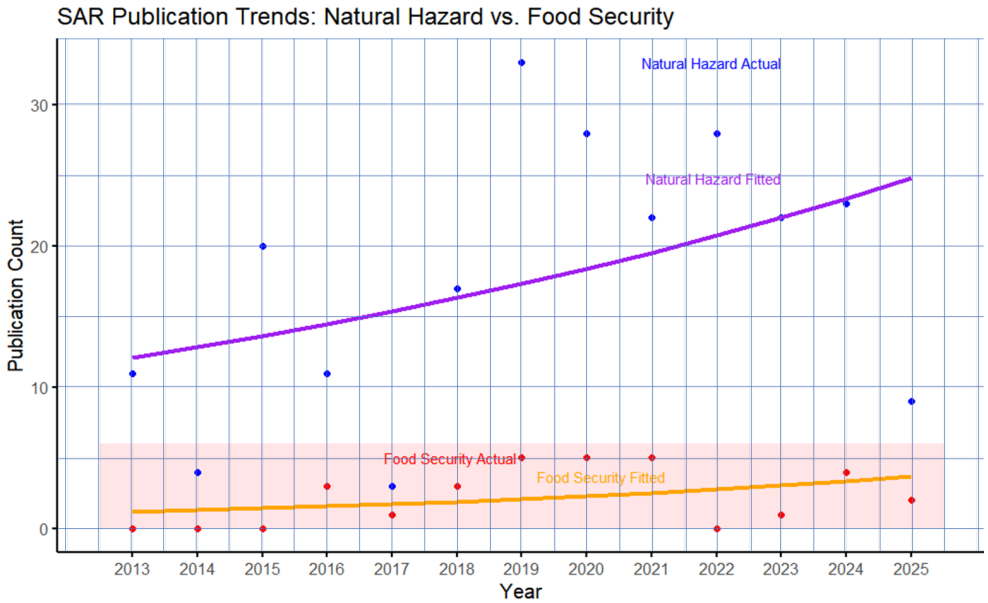
Fig. 13. Statistical distribution and Poisson regression as functions of numbers of publications and years of publications of articles

Figure 14 illustrates the discrepancy between public policies and research on the use of SAR in Indonesia. Although it cannot be considered the sole factor that influenced government action in issuing regulations to address the crises (food and hazard resilience), the output and contribution of scholarly research were intuitively disjointed and diverge from what the government needed.

In general, Indonesian SAR researchers hesitated to publish in reputable journals due to high article-processing charges (APCs) and lengthy peer-review times. Limited access to user-friendly open-source SAR software and expensive commercial options further complicated their work. Consequently, researchers in the disaster and food security fields often chose mid-level publishers, thus reducing the policy impacts of their findings.

Our review showed that approximately 83% of the publications required APCs, while just over 16% appeared in hybrid or fee-free journals. Specifically for the food security theme, 83.3% of the articles were published in journals that required APCs, and 16.7% appeared in hybrid journals or those without publication fees. For the disaster theme, 83.1% of the publications were found in journals with APCs, while 16.9% appeared in hybrid or fee-free journals. These numbers reflect growing concerns over publication costs – especially for authors in the Global South (like in Indonesia) [54]. To overcome these barriers, researchers have sought combined funding or support from foreign colleagues, and they have even used their personal funds to pay the APCs [55]; this highlights the ongoing challenges in making research accessible.
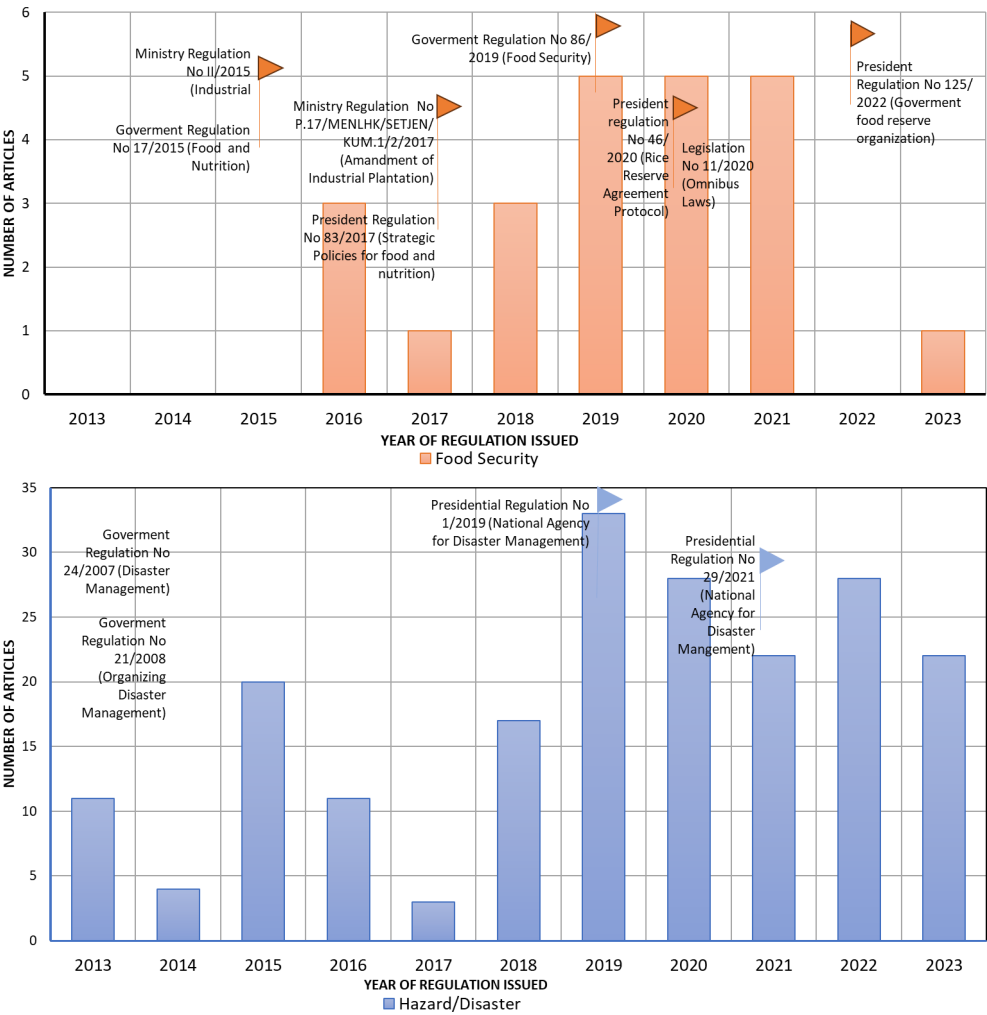
Fig. 14. Graph shows SAR articles on topics of food security and natural disasters as related to issuance timelines of regulations

4.   Summary and Conclusion

This study analyzed 243 peer-reviewed articles (2013–2025) and revealed a striking thematic imbalance: 90% of the pertinent research focused on natural disasters (driven by events such as the Palu earthquake and the Riau haze crisis), while only 10% addressed food security (despite its critical role in national stability). This gap contrasts sharply with legislative trends, where food security regulations being updated much more frequently than disaster-management frameworks are; this highlights the misalignment between research output and policy priorities. Geographically, SAR case studies are clustered in areas such as Greater Jakarta, Central

Sulawesi, and Yogyakarta – mostly reflecting their vulnerabilities to hazards and agricultural pressures. A temporal analysis showed spikes in publications after major disasters (e.g., the Merapi eruption, Lombok earthquake), thus underscoring the reactive nature of SAR research. Meanwhile, chronic issues such as land subsidence and deforestation remain underrepresented despite their long-standing impacts.

Publisher preferences further illustrate systemic challenges, as Indonesian researchers prefer Elsevier and Springer (with hybrid access) over MDPI and IEEE (gold open access). High APCs and limited access to SAR software have hindered wider dissemination; more than 80% of publications require APCs, thus exacerbating inequities for researchers in the Global South and indirectly affecting policymakers' abilities to access and read them (allegedly limiting their capacities to draft policy implementations).

While the technical capabilities of SAR (such as cloud-penetrating imaging and land-use monitoring) are well-documented, their integration into policymaking remains minimal. This gap suggests a "bottleneck" in which academics and policymakers operate in silos: researchers prioritize technical advances, while regulators ignore scientific evidence in favor of political or urgent needs. To bridge this gap, we advocate the following: a science-policy dialogue platform to align SAR research with legislative agendas; targeted funding for underrepresented disasters (e.g., coastal erosion, slow-onset disasters) and eastern Indonesia; open-access initiatives to reduce financial barriers and increase research accessibility.

In conclusion, the SAR technology has great potential to enhance Indonesia's disaster-resilience and food security. To realize this potential, however, academic efforts must be pursued, interdisciplinary cooperation fostered, and evidence-based policymaking prioritized. SAR's transformative power runs the risk of staying in journals rather than advancing practical solutions for the communities that are most affected by these dual crises if systemic change is not implemented.

Funding

CRediT Author Contribution

N. S.: conceptualization, methodology, validation, writing – original draft, writing – review & editing.

A. S.: supervision, writing – review & editing.

G. P. D.: conceptualization, methodology, validation, formal analysis, writing – original draft.

D. A. N.: validation, visualization, writing – review & editing.

A. D.: formal analysis, writing – review & editing.

E. T.: formal analysis, visualization.

J. W.: supervision, writing – review & editing.

B. G.: formal analysis, visualization.

References

[1] Resosudarmo I.A.P., Tacconi L., Sloan S., Hamdani F.A.U., Subarudi, Alviya I., Muttaqin M.Z.: *Indonesia's land reform: Implications for local livelihoods and climate change*. Forest Policy Economics, vol. 108, 2019, 101903. https://doi.org/10.1016/j.forpol.2019.04.007.

[2] Hakim A.M.Y., Matsuoka M., Baja S., Rampisela D.A., Arif S.: *Predicting land cover change in the Mamminasata area, Indonesia, to evaluate the spatial plan*. ISPRS International Journal of Geo-Information, vol. 9(8), 2020, 481. https://doi.org/10.3390/ijgi9080481.

[3] Purnomo E.P., Ramdani R., Agustiyara, Tomaro Q.P.V., Samidjo G.S.: *Land ownership transformation before and after forest fires in Indonesian palm oil plantation areas*. Journal of Land Use Science, vol. 14(1), 2019, pp. 37–51. https://doi.org/10.1080/1747423X.2019.1614686.

[4] Bou Dib J., Alamsyah Z., Qaim M.: *Land-use change and income inequality in rural Indonesia*. Forest Policy Economics, vol. 94, 2018, pp. 55–66. https://doi.org/10.1016/j.forpol.2018.06.010.

[5] Nurprabowo A., Awang S.A., Hardwinarto S., Dharmawan B., Daulay M.H., Maryudi A.: *Poor science meets political neglect: Land use changes of high conservation value forests in Indonesia*. Forest and Society, vol. 5(2), 2021, pp. 199–208. https://doi.org/10.24259/fs.v5i2.13451.

[6] Surandoko T.: *The impact of provincial forest subsidies on deforestation in Indonesia*. Jurnal Perencanaan Pembangunan Indonesia [Indonesian Journal of Development Planning], vol. 5(2), 2021, pp. 250–68. https://doi.org/10.36574/jpp.v5i2.202.

[7] Kelly-Fair M., Gopal S., Koch M., Pancasakti Kusumaningrum H., Helmi M., Khairunnisa D., Kaufman L.: *Analysis of land use and land cover changes through the lens of SDGs in Semarang, Indonesia*. Sustainability, vol. 14(13), 2022, 7592. https://doi.org/10.3390/su14137592.

[8] Nugroho A.A., Purnama M.Y.I., Fauzia L.R.: *Clustering and regional growth in the housing market: Evidence from Indonesia*. Jurnal Keuangan dan Perbankan, vol. 24(1), 2020, pp. 83-94. https://doi.org/10.26905/jkdp.v24i1.3565.

[9] Rustiadi E., Veriasa T.O.: *Towards inclusive Indonesian forestry: An overview of a spatial planning and agrarian perspective*. Jurnal Manajemen Hutan Tropika [Journal of Tropical Forest Management], vol. 28(1), 2022, pp. 60–71. https://doi.org/10.7226/jtfm.28.1.60.

[10] Wibowo A.H., Larasati D.: *Incremental housing development; An approach in meeting the needs of low cost housing In Indonesia*. IOP Conference Series: Earth and Environmental Science, vol. 152, 2018, 012006. https://doi.org/10.1088/1755-1315/152/1/012006.

[11] Larivière V., Haustein S., Mongeon P.: *The oligopoly of academic publishers in the digital era*. PLoS One, vol. 10(6), 2015, e0127502. https://doi.org/10.1371/journal.pone.0127502.

[12] Nishikawa-Pacher A.: *Who are the 100 largest scientific publishers by journal count? A webscraping approach*. Journal of Documentation, vol. 78(7), 2022, pp. 450–63. https://doi.org/10.1108/JD-04-2022-0083.

[13] Maddi A., Maisonobe M., Boukacem-Zeghmouri C.: *Geographical and disciplinary coverage of open access journals: OpenAlex, Scopus, and WoS*. PLoS One, vol. 20(4), 2025, e0320347. https://doi.org/10.1371/journal.pone.0320347.

[14] Qader S.H., Utazi C.E., Priyatikanto R., Najmaddin P., Hama-Ali E.O., Khwarahm N.R., Tatem A.J., Dash J.: *Exploring the use of Sentinel-2 datasets and environmental variables to model wheat crop yield in smallholder arid and semi-arid farming systems*. Science of The Total Environment, vol. 869, 2023, 161716. https://doi.org/10.1016/j.scitotenv.2023.161716.

[15] Thorp K.R., Drajat D.: *Deep machine learning with Sentinel satellite data to map paddy rice production stages across West Java, Indonesia*. Remote Sensing of Environment, vol. 265, 2021, 112679. https://doi.org/10.1016/j.rse.2021.112679.

[16] Aguilar F.J., Rodríguez F.A., Aguilar M.A., Nemmaoui A., Álvarez-Taboada F.: *Forestry applications of space-borne LiDAR sensors: A worldwide bibliometric analysis*. Sensors, vol. 24(4), 2024, 1106. https://doi.org/10.3390/s24041106.

[17] Yusoff N.M., Muharam F.M., Takeuchi W., Darmawan S., Abd Razak M.H.: *Phenology and classification of abandoned agricultural land based on ALOS-1 and 2 PALSAR multi-temporal measurements*. International Journal of Digital Earth, vol. 10(2), 2017, pp. 155–174. https://doi.org/10.1080/17538947.2016.1216615.

[18] Trisasongko B.H., Paull D.J.: *L-band SAR for estimating aboveground biomass of rubber plantation in Java Island, Indonesia*. Geocarto International, vol. 35(12), 2020, pp. 1327–1342. https://doi.org/10.1080/10106049.2019.1573855.

[19] Gandharum L., Mulyani M.E., Hartono D.M., Karsidi A., Ahmad M.: *Remote sensing versus the area sampling frame method in paddy rice acreage estimation in Indramayu regency, West Java province, Indonesia*. International Journal of Remote Sensing, vol. 42(5) 2021, pp. 1738–67. https://doi.org/10.1080/01431161.2020.1842541.

[20] Lee H., Kim S., Lim D., Bae S.H., Kang L.H., Kim S.: *Two-step approach toward alignment of spatiotemporal wide-area unmanned aerial vehicle imageries*. Drones, vol. 7(2), 2023, 131. https://doi.org/10.3390/drones7020131.

[21] Letsoin S.M.A., Purwestri R.C., Perdana M.C., Hnizdil P., Herak D.: *Monitoring of paddy and maize fields using Sentinel-1 SAR data and NGB images: A case study in Papua, Indonesia*. Processes, vol. 11(3) 2023, 647. https://doi.org/10.3390/pr11030647.

[22] Saepuloh A., Koike K., Urai M., Sumantyo J.T.S.: *Identifying surface materials on an active volcano by deriving dielectric permittivity from polarimetric SAR data*. IEEE Geoscience and Remote Sensing Letters, vol. 12(8), 2015, pp. 1620–1624. https://doi.org/10.1109/LGRS.2015.2415871.

[23] Lissak C., Bartsch A., De Michele M., Gomez C., Maquaire O., Raucoules D., Roulland T.: *Remote sensing for assessing landslides and associated hazards*. Surveys in Geophysics, vol. 41(6), 2020, pp. 1391–1435. https://doi.org/10.1007/s10712-020-09609-1.

[24] Cassidy M., Ebmeier S.K., Helo C., Watt S.F.L., Caudron C., Odell A., Spaans K., Kristianto P., Triastuty H., Gunawan H., Castro J.M.:*Explosive eruptions with little warning: experimental petrology and volcano monitoring observations from the 2014 eruption of Kelud, Indonesia*. Geochemistry, Geophysics, Geosystems, vol. 20(8), 2019, pp. 4218–47. https://doi.org/10.1029/2018GC008161.

[25] Kimijima S., Sakakibara M., Nagai M.: *Characterizing time-series roving artisanal and small-scale gold mining activities in Indonesia using Sentinel-1 data*. International Journal Environmental Research and Public Health, vol. 19(10), 2022, 6266. https://doi.org/10.3390/ijerph19106266.

[26] Worthington T.A., zu Ermgassen P.S.E., Friess D.A., Krauss K.W., Lovelock C.E., Thorley J., Tingey R., Woodroffe C.D., Bunting P., Cormier N., Lagomasino D., Lucas R., Murray N.J., Sutherland W.J., Spalding M.: *A global biophysical typology of mangroves and its relevance for ecosystem structure and deforestation*. Scientific Reports, vol. 10, 2020, 14652. https://doi.org/10.1038/s41598-020-71194-5.

[27] Kiswanto, Tsuyuki S., Mardiany, Sumaryono.: *Completing yearly land cover maps for accurately describing annual changes of tropical landscapes*. Global Ecology and Conservation, vol. 13, 2018, e00384. https://doi.org/10.1016/j.gecco.2018.e00384.

[28] Simanjuntak R.M., Kuffer M., Reckien D.: *Object-based image analysis to map local climate zones: The case of Bandung, Indonesia*. Applied Geography, vol. 106, 2019, pp. 108–121. https://doi.org/10.1016/j.apgeog.2019.04.001.

[29] Habibie M.I., Noguchi R., Matsushita S., Ahamed T.: *Development of micro-level classifiers from land suitability analysis for drought-prone areas in Indonesia*. Remote Sensing Applications: Society and Environment, vol. 20, 2020, 100421. https://doi.org/10.1016/j.rsase.2020.100421.

[30] Feng Z., Feng G., Chen H., Xu W., Li Z., He L., Ren Z.: *A block ramp errors correction method of planet subpixel offset: application to the 2018 Mw 7.5 Palu earthquake, Indonesia*. IEEE Access, vol. 7, 2019, pp. 174924–174931. https://doi.org/10.1109/ACCESS.2019.2956198.

[31] Wang Y., Feng W., Chen K., Samsonov S.: *Source characteristics of the 28 September 2018 Mw 7.4 Palu, Indonesia, Earthquake Derived from the Advanced Land Observation Satellite 2 Data*. Remote Sensing, vol. 11(17), 2019, 1999. https://doi.org/10.3390/rs11171999.

[32] Bao H., Ampuero J.P., Meng L., Fielding E.J., Liang C., Milliner C.W.D., Feng T., Huang H.: *Early and persistent supershear rupture of the 2018 magnitude 7.5 Palu earthquake*. Nature Geoscience, vol. 12(3), 2019, pp. 200–205. https://doi.org/10.1038/s41561-018-0297-z.

[33] Simons W., Broerse T., Shen L., Kleptsova O., Nijholt N., Hooper A., Pietrzak J., Morishita Y., Naeije M., Lhermitte S., Herman M., Sarsito D.A., Efendi J., Sofian, Govers R., Vigny C., Zainal Abidin H., Pramono G., Nugroho C., Visser P., Riva R.: *A tsunami generated by a strike-slip event: Constraints from GPS and SAR data on the 2018 Palu earthquake*. Journal of Geophysical Research: Solid Earth, vol. 127(12), 2022, e2022JB024191. https://doi.org/10.1029/2022JB024191.

[34] Aisyah N., Iguchi M., Subandriyo, Budisantoso A., Hotta K., Sumarti S.: *Combination of a pressure source and block movement for ground deformation analysis at Merapi volcano prior to the eruptions in 2006 and 2010*. Journal of Volcanology and Geothermal Research, vol. 357, 2018, pp. 239–253. https://doi.org/10.1016/j.jvolgeores.2018.05.001.

[35] Arjasakusuma S., Swahyu Kusuma S., Rafif R., Saringatin S., Wicaksono P.: *Combination of Landsat 8 OLI and Sentinel-1 SAR time-series data for mapping*

paddy fields in parts of West and Central Java Provinces, Indonesia. ISPRS International Journal of Geo-Information, vol. 9(11), 2020, 663. https://doi.org/10.3390/ijgi9110663.

[36] Ramdani F., Setiani P., Setiawati D.A.: *Analysis of sequence earthquake of Lombok Island, Indonesia*. Progress in Disaster Science, vol. 4, 2019, 100046. https://doi.org/10.1016/j.pdisas.2019.100046.

[37] Solikhin A., Thouret J.C., Liew S.C., Gupta A., Sayudi D.S., Oehler J.F., Kassouk Z.: *High-spatial-resolution imagery helps map deposits of the large (VEI 4) 2010 Merapi Volcano eruption and their impact*. Bulletin of Volcanology vol. 77(3), 2015, 20. https://doi.org/10.1007/s00445-015-0908-0.

[38] Abidin H.Z., Andreas H., Gumilar I., Sidiq T.P., Fukuda Y.: *Land subsidence in coastal city of Semarang (Indonesia): Characteristics, impacts and causes*. Geomatics, Natural Hazards and Risk, vol. 4(3), 2013, pp. 226–240. https://doi.org/10.1080/19475705.2012.692336.

[39] Zhang H., Liu X., Xie Y., Gou Q., Li R., Qiu Y., Hu Y., Huang B.: *Assessment and improvement of urban resilience to flooding at a subdistrict level using multisource geospatial data: Jakarta as a case study*. Remote Sensing, vol. 14(9), 2022, 2010. https://doi.org/10.3390/rs14092010.

[40] Purwandana A., Cuypers Y., Surinati D., Iskandar M.R., Bouruet-Aubertot P.: *Observed internal solitary waves in the northern Bali waters, Indonesia*. Regional Studies in Marine Science vol. 57, 2023, 102764. https://doi.org/10.1016/j.rsma.2022.102764.

[41] Vignudelli S., Birol F., Benveniste J., Fu L.L., Picot N., Raynal M., Roinard H.: *Satellite altimetry measurements of sea level in the coastal zone*. Surveys in Geophysics, vol. 40(6), 2019, pp. 1319–1349. https://doi.org/10.1007/s10712-019-09569-1.

[42] Hébert H., Occhipinti G., Schindelé F., Gailler A., Pinel-Puysségur B., Gupta H.K., Rolland L., Lognonné P., Lavigne F., Meilianda E., Chapkanski S., Crespon F., Paris A., Heinrich P., Monnier A., Jamelot A., Reymond D.: *Contributions of space missions to better tsunami science: Observations, models and warnings*. Surveys in Geophysics, vol. 41(6), 2020, pp. 1535–1581. https://doi.org/10.1007/s10712-020-09616-2.

[43] Perissin D.: *Interferometric SAR multitemporal processing: Techniques and applications*, [in:] Ban Y. (ed.), *Multitemporal Remote Sensing: Methods and Applications*, Remote Sensing and Digital Image Processing, vol. 20, Springer, Cham 2016, pp. 145–176. https://doi.org/10.1007/978-3-319-47037-5_8.

[44] Shimada M. (ed.): *Imaging from Spaceborne and Airborne SARs, Calibration, and Applications.* CRC Press, Boca Raton 2018. https://doi.org/10.1201/b21909.

[45] Thapa S., Chatterjee R.S., Singh K.B., Kumar D.: *Land subsidence monitoring using PS-InSAR technique for L-band SAR data*. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, vol. XLI-B7, 2016, pp. 995–7. https://doi.org/10.5194/isprs-archives-XLI-B7-995-2016.

[46] Widodo J., Arief R., Dinanta G.P., Setyaningrum N., Setiyoko A., Putra A.P., Oktaviani A., Wisyanto, Santoso E.W., Hidayat N., Awaluddin, Kurniawan F., Pradono M.H.H., Razi P., Izumi Y., Sumantyo J.T.S.: *Time series land subsidence analysis based on persistent scattered interferometric synthetic aperture radar method of Jakarta city region using Terra SAR X spaceborne data*, [in:] *2022 International Conference on Radar, Antenna, Microwave, Electronics, and Telecommunications (ICRAMET)*, IEEE, 2022, pp. 106–113. https://doi.org/10.1109/ICRAMET56917.2022.9991211.

[47] Walter T.R., Subandriyo J., Kirbani S., Bathke H., Suryanto W., Aisyah N., Darmawan H., Jousset P., Luehr B.-G., Dahm T.: *Volcano-tectonic control of Merapi's lava dome splitting: The November 2013 fracture observed from high resolution TerraSAR-X data*. Tectonophysics, vol. 639, 2015, pp. 23–33. https://doi.org/10.1016/j.tecto.2014.11.007.

[48] Yulianto F., Sofan P., Khomarudin M.R., Haidar M.: *Extracting the damaging effects of the 2010 eruption of Merapi volcano in Central Java, Indonesia*. Natural Hazards, vol. 66(2), 2013, pp. 229–247. https://doi.org/10.1007/s11069-012-0438-4.

[49] Neta Y., Evendia M., Firmansyah A.A.: *Implications of omnibus law on job creation towards regulations in decentralization perspective*. Cepalo, vol. 6(1), 2022, pp. 57–68. https://doi.org/10.25041/cepalo.v6no2.2683.

[50] Dong X., Quegan S., Yumiko U., Hu C., Zeng T.: *Feasibility study of C- and L-band SAR time series data in tracking Indonesian plantation and natural forest cover changes*. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 8(7), 2015, pp. 3692–3699. https://doi.org/10.1109/JSTARS.2015.2400439.

[51] Shiraishi T., Motohka T., Thapa R.B., Watanabe M., Shimada M.: *Comparative assessment of supervised classifiers for land use–land cover classification in a tropical region using time-series PALSAR mosaic data*. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 7(4), 2014, pp. 1186–1199. https://doi.org/10.1109/JSTARS.2014.2313572.

[52] Darmawan S., Carolita I., Hernawati R., Dirgahayu D., Agustan, Permadi D.A., Sari D.K., Suryadini W., Wiratmoko D., Kunto Y.: *The potential scattering model for oil palm phenology based on spaceborne X-, C-, and L-band polarimetric SAR imaging*. Journal of Sensors, vol. 2021(1), 2021, 6625774. https://doi.org/10.1155/2021/6625774.

[53] Dharmawan I.A., Rahadianto M.A.E., Henry E., Endyana C., Aufaristama M.: *Application of high-resolution remote-sensing data for land use land cover mapping of university campus*. The Scientific World Journal, vol. 2021(1), 2021, 5519011. https://doi.org/10.1155/2021/5519011.

[54] Borrego Á.: *Article processing charges for open access journal publishing: A review*. Learned Publishing, vol. 36(3), 2023, pp. 359–378. https://doi.org/10.1002/leap.1558.

[55] Smith A.C., Merz L., Borden J.B., Gulick C.K., Kshirsagar A.R., Bruna E.M.: *Assessing the effect of article processing charges on the geographic diversity of*

authors using Elsevier's "Mirror Journal" system. Quantitative Science Studies, vol. 2(4), 2021, pp. 1123–1143. https://doi.org/10.1162/qss_a_00157.

[56] Jindo K., Kozan O., Iseki K., Maestrini B., van Evert F.K., Wubengeda Y., Arai E., Shimabukuro Y.E., Sawada Y., Kempenaar C.: *Potential utilization of satellite remote sensing for field-based agricultural studies*. Chemical Biological Technologies in Agriculture, vol. 8, 2021, 58. https://doi.org/10.1186/s40538-021-00253-4.

[57] Clauss K., Ottinger M., Kuenzer C.: *Mapping rice areas with Sentinel-1 time series and superpixel segmentation*. International Journal of Remote Sensing, vol. 39(5), 2018, pp. 1399–1420. https://doi.org/10.1080/01431161.2017.1404162.

[58] Setiyono T.D., Quicho E.D., Holecz F.H., Khan N.I., Romuga G., Maunahan A., Garcia C., Rala A., Raviz J., Collivignarelli F., Gatti L., Barbieri M., Phuong D.M., Minh V.Q., Vo Q.T., Intrman A., Rakwatin P., Sothy M., Veasna T., Pazhanivelan S., Mabala M.R.O.: *Rice yield estimation using synthetic aperture radar (SAR) and the ORYZA crop growth model: development and application of the system in South and South-east Asian countries*. International Journal of Remote Sensing, vol. 40(21), 2019, pp. 8093–8124. https://doi.org/10.1080/01431161.2018.1547457.

[59] Arjasakusuma S., Kusuma S.S., Vetrita Y., Prasasti I., Arief R.: *Monthly burned-area mapping using multi-sensor integration of Sentinel-1 and Sentinel-2 and machine learning: Case study of 2019's fire events in South Sumatra Province, Indonesia*. Remote Sensing Applications: Society and Environment, vol. 27, 2022, 100790. https://doi.org/10.1016/j.rsase.2022.100790.

[60] Uppala D., Somepalli V., Venkata R.K., Rama S.M.V.: *Identification of optimal single date for rice crop discrimination and relationships between backscatter and biophysical parameters using RISAT-1 hybrid polarimetric SAR data*. Geocarto International, vol. 36(17), 2021, pp. 2010–2022. https://doi.org/10.1080/10106049.2019.1687589.

[61] Badigannavar A., Teme N., de Oliveira A.C., Li G., Vaksmann M., Viana V.E., Ganapathi T.R., Sarsu F.: *Physiological, genetic and molecular basis of drought resilience in sorghum [Sorghum bicolor (L.) Moench]*. Indian Journal of Plant Physiology, vol. 23(4), 2018, pp. 670–688. https://doi.org/10.1007/s40502-018-0416-2.

[62] Manago N., Hongo C., Sofue Y., Sigit G., Utoyo B.: *Transplanting date estimation using Sentinel-1 satellite data for paddy rice damage assessment in Indonesia*. Agriculture, vol. 10(12), 2020, 625. https://doi.org/10.3390/agriculture10120625.

[63] Wakabayashi H., Hongo C., Igarashi T., Asaoka Y., Tjahjono B., Permata I.: *Flooded rice paddy detection using Sentinel-1 and PlanetScope data: A case study of the 2018 spring flood in West Java, Indonesia*. IEEE Journal of Selected Topics Applied Earth Observations and Remote Sensing, vol. 14, 2021, pp. 6291–6301. https://doi.org/10.1109/JSTARS.2021.3083610.

[64] Razak J.A. binti A., Shariff A.R. bin M., Ahmad N. bin, Ibrahim Sameen M.: *Mapping rubber trees based on phenological analysis of Landsat time series data-sets*. Geocarto International, vol. 33(6), 2017, pp. 627-650. https://doi.org/10.1080/10106049.2017.1289559.

[65] J.S.H., Wich S., Widayati A., Koh L.P.: *Detecting industrial oil palm plantations on Landsat images with Google Earth Engine*. Remote Sensing Applications: Society and Environment, vol. 4, 2016, pp. 219–224. https://doi.org/10.1016/j.rsase.2016.11.003.

[66] Torbick N., Ledoux L., Salas W., Zhao M.: *Regional mapping of plantation extent using multisensor imagery*. Remote Sensing, vol. 8(3), 2016, 236. https://doi.org/10.3390/rs8030236.

[67] Danudirdjo D., Hirose A.: *Anisotropic phase unwrapping for synthetic aperture radar interferometry*. IEEE Transaction on Geoscience and Remote Sensing, vol. 53(7), 2015, pp. 16–26. https://doi.org/10.1109/TGRS.2015.2391191.

[68] Razi P., Sumantyo J.T.S., Perissin D., Kuze H., Chua M.Y., Panggabean G.F.: *3D land mapping and land deformation monitoring using persistent scatterer interferometry (PSI) ALOS PALSAR: validated by Geodetic GPS and UAV*. IEEE Access, vol. 6, 2018, pp. 12395–12404. https://doi.org/10.1109/ACCESS.2018.2804899.

[69] Saepuloh A., Haeruddin H., Heriawan M.N., Kubo T., Koike K., Malik D.: *Application of lineament density extracted from dual orbit of synthetic aperture radar (SAR) images to detecting fluids paths in the Wayang Windu geothermal field (West Java, Indonesia)*. Geothermics, vol. 72, 2018, pp. 145–155. https://doi.org/10.1016/j.geothermics.2017.11.010.

[70] Suroso D.S.A., Firman T.: *The role of spatial planning in reducing exposure towards impacts of global sea level rise case study: Northern coast of Java, Indonesia*. Ocean and Coastal Management, vol. 153, 2018, pp. 84–97. https://doi.org/10.1016/j.ocecoaman.2017.12.007.

[71] Bacques G., de Michele M., Foumelis M., Raucoules D., Lemoine A., Briole P.: *Sentinel optical and SAR data highlights multi-segment faulting during the 2018 Palu-Sulawesi earthquake (Mw 7.5)*. Scientific Reports, vol. 10, 2020, 9103. https://doi.org/10.1038/s41598-020-66032-7.

[72] Hoyt A.M., Chaussard E., Seppalainen S.S., Harvey C.F.: *Widespread subsidence and carbon emissions across Southeast Asian peatlands*. Nature Geoscience, vol. 13(6), 2020, pp. 435–40. https://doi.org/10.1038/s41561-020-0575-4.

[73] Kirschbaum D., Stanley T.: *Satellite-based assessment of rainfall-triggered landslide hazard for situational awareness*. Earth's Future, vol. 6(3), 2018, pp. 505–523. https://doi.org/10.1002/2017EF000715.

[74] Robinson T.R., Rosser N., Walters R.J.: *The spatial and temporal influence of cloud cover on satellite-based emergency mapping of earthquake disasters*. Scientific Reports, vol. 9, 2019, 12455. https://doi.org/10.1038/s41598-019-49008-0.

Appendix

Table A1. Samples of some laws and regulations that are related to food security issues in Indonesia

Government Institution	Domain of Authority	Regulation/National Law	Interest		Potential research [SAR]
			Objective	Historical/Background	
Food Plantation					
House of Representatives	Legislator	18/2012 (about food)	The implementation of food to meet the basic needs of Indonesian citizens based on the principles of sovereignty, independence, benefits, equity, sustainability, and justice as well as increasing food access for the community and providing added value and competitiveness of food commodities in domestic and foreign markets	The 1945 Constitution of the Republic of Indonesia	The regulation was released before the timelines of this study
		11/2020 (about OMNIBUS LAW on Job Creation)	Regulations on agricultural endowment land areas – especially for food security and the protection of these areas from land-use change as well as encouraging the adequacy of consumption needs and or food reserves that can come from domestic production and imports while protecting the interests of farmers	Realizing a prosperous Indonesian society based on Pancasila and the Republic of Indonesia's 1945 constitution while defending citizens' rights to a respectable standard of living	[19, 56–59]

Government Institution	Domain of Authority	Regulation/National Law	Interest		Potential research [SAR]
			Objective	Historical/ Background	
Government Regulation	Executives	17/2015 (Food Security and Nutrition)	Regulations governing the conditions of adequate food and good nutrition for the community by considering food reserves, diversity, and food distribution as well as anticipation of food crises	Article 28 § (4), Article 43, Article 45 § (3), Article 48 § (2) Article 112, Article 116, and Article 131 § (2) of constitution No. 18/2012	No article about food security older than 2015 in this study
		86/2019 (Food Safety)	Regulations on food handling, including proper sanitary procedures and the detection of hazardous contaminants for food, from manufacturing to distribution to community consumption	Article 88 § (4), Article 94 § (3), Article ll2, and Article 131 § (21) of constitution No. 18 of 2012	[57, 58, 60]
Presidential Regulation	Executives (National Program)	83/2017 (Strategy Food Security and Nutrition)	Regulations to enforce strategic food and nutrition policies, which take considerations of food availability, cost, and utilization, encourage community nutrition, and establish institutions for food and nutrition through larger national food production	Article 4 § (1) of the Constitution of the Republic of Indonesia and Act No. 18/2012 on food.	No article about food security older than 2017 in this study

Ministry of Agriculture	Executives (organizing government affairs and supervising agricultural policies)	38/PERMENTAN/KN.130/8/2018 (Management of Government Rice Reserves)	Determination of national rice-reserve capacity, which is managed by the government, monitoring, evaluation, and reporting schemes for rice-reserve adequacy	Article 8 of Regulation Government No. 17/2015 on Food Security and Nutrition.	[60]
Presidential Regulation	Executives (National Program)	66/2021 (National Food Agency)	The coordination and development of food-availability policies, the monitoring of food prices and supplies, the acquisition, distribution, and management of food reserves through state-owned enterprises, and the implementation of the development of food-information systems and guidance to relevant stakeholders	Article 129 constitution No. 18/2012 concerning food as amended by constitution No. 11/2020 about *Cipta Kerja*	[35, 61, 62]
		125/2022 (implementation of government food reserves)	The National Food Agency was established to secure the sustainability of national food reserves and prevent food crises, and regulations on the oversight of government food reserves ensure a stable food supply in the nation in accordance with community requirements	Government Regulation No. 12/2015 on Food Security and Nutrition, Article 12	[15, 19, 35, 62, 63]

Industrial Plantation

Government Institution	Domain of Authority	Regulation/National Law	Interest		Potential research [SAR]
			Objective	Historical/ Background	
House of Representatives	Legislator	18/2004 (Industrial Plantation)	The definitions of plantations, the varieties of plants, business activities, actors in business, and those who implement plantation activities are covered, as well activities in the plantation-production industries	The 1945 Constitution of the Republic of Indonesia	The regulation was released before the timeline of this study
Government Regulation	Executive	39/2014 (Plantation)	Revise Legislation No. 18/2004 and consider the changing dynamics of a more sustainable and environmentally friendly plantation industry	18/2004 about industrial plantations	No articles about this topic were released before 2015
Ministry of Environment and Forestry	Executives (organizing government affairs and supervising industrial plantation policies)	P.12/Menlhk-II/2015	Provides policies on forest-product utilization, business work plans, spatial planning, protected areas, agroforestry, plantation-business licenses, and logging and industrial-plantation regulations	Article 38 § (6) and Article 39 § (2) of Government Regulation No. 6/2007	No articles about this topic were released before 2015
		P.17/MENLHK/SETJEN/KUM.1/2/2017	Provides revision of P.12/Menlhk-II/2015, and regulates peatland ecosystems and forest areas	P.12/Menlhk-II/2015	[50, 64–66]

Table A2. Sample of laws and regulations that are related to natural disaster issues in Indonesia

Government Institution	Domain of Authority	Regulation/ National Law	Interest		Potential Research on SAR
			Objective	Historical/ Background	
Government Regulation	Executives (National Program)	24/2007 (disaster management)	Provides a definition of a disaster, with disaster types divided into three parts: natural disasters, non-natural disasters, and social disasters. The implementation of disaster management in the form of prevention, preparedness, early warning, mitigation, emergency response, and rehabilitation is part of this legislation. Arrangements regarding post-disaster recovery and emergency assistance schemes are explained in this regulation as well	The 1945 Constitution of the Republic of Indonesia	The regulation was released before the timeline of this study
		21/2008 (Organizing Disaster Management)	Explains the disaster-management-planning mechanism under non-disaster conditions and in the event of a disaster, compiles disaster-risk reduction, conducts prevention and disaster-risk-analysis guidelines and coordinates, and provides commitments to disaster management through physical and non-physical efforts and other supporting facilities	Article 50 § (2), Article 58 § (2), and Article 59 § (2) of Constitution No. 24/2007	The regulation was released before the timeline of this study
Presidential Regulation	Executives (National Program)	1/2019 (National Agency for Disaster Management)	Statement about the establishment of institutions that specifically deal with disaster issues and their authority in accountability, as well as their obligations and authorities in disaster management	Regulation No. 24/2007	[50, 51, 67–70]
		29/2021 (National Agency for Disaster Management)	The addition of executive positions in the nomenclature and deputies in the field of disaster-emergency management that can be filled by the national army	Regulation No. 29/2019	[71–74]