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FINAL REPORT

Advancing SDG 11 Through Capacity Building and Science-Based Urban Spatial Planning (SciBUSP) in Southeast Asia: Big Earth Data Solutions for Sustainable Urban Planning



CBA2025-02SY-SUTRISNO

2026

BRIN
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VAST

CBAS
INTERNATIONAL RESEARCH CENTER OF BIG DATA
FOR SUSTAINABLE DEVELOPMENT GOALS
可持续发展大数据国际研究中心

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4. **Prabu Kresna Putra** (M), Research Centre for Data and Information Sciences, National Research and Innovation Agency (BRIN), Indonesia
5. **Boby Bagja Pratama** (M), Research Centre for Ecology, National Research and Innovation Agency (BRIN), Indonesia
6. **Ayub Sugara** (M), Department of Marine Sciences, Faculty of Agriculture, Bengkulu University, Indonesia
7. **Aninda Wisaksanti Rudiastuti** (F), Research Centre for Conservation of Marine and Inland Water Resources, National Research and Innovation Agency (BRIN), Indonesia
8. **Robby Arifandri** (M), Research Centre for Artificial Intelligence and Cyber Security, National Research and Innovation Agency (BRIN), Indonesia
9. **Dionysius Bryan Sencaki** (M), Research Centre for Geoinformatic, National Research and Innovation Agency (BRIN), Indonesia
10. **Hari Prayogi** (M), Research centre for Limnology and water resources, National Research and Innovation Agency (BRIN), Indonesia

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1. Summary

The Sustainable Development Goal (SDG) 11 objectives in Southeast Asia, especially in Indonesia, Malaysia, and Vietnam, are intricately connected to urban spatial planning as a vital instrument for realising sustainable cities. Since the Southeast Asia is urbanizing rapidly, this project initiated the development of a prototype for Science-Based Urban Spatial Planning (SciBUSP), recognising the imperative for a novel, data-informed approach to urban planning. SciBUSP amalgamates geospatial intelligence, satellite remote sensing, and AI-driven analytics to deliver real-time evidence-based insights that can guide policy and decision-making processes. Those technologies have greatly expanded to planners, yet the human and institutional capacity to use those resources coherently remains uneven across region. This project addresses that gap by combining a concept and practical toolkit with a structured capacity-building programme and a rigorous evaluation framework. As the SciBUSP initiative aims to strengthen the capacity of the early careers professional in Southeast Asia, a comprehensive capacity buildings programme was implemented, consisting of a Training of Trainers (ToT), followed by a series of national and regional workshops within Southeast Asia

The project pursues objective, there is to implement a comprehensive capacity-building program that empowers early careers, through training workshops and collaborative projects, enabling them to manage and apply Big Earth Data tools effectively through the SciBUSP initiative. The methodology comprised preparatory coordination, co-design dan development of SciBUSP toolkit and instruments through three focus group discussions, and a hybrid kick-off meeting, prior to cascading capacity building an its evaluations.

A ToT was held in Jakarta from April 13 to 19, 2026 for early careers from Indonesia, Malaysia, and China, Experts also invited from Indonesia, Bangladesh and China. The TOT resulted five qualified as Master Trainers, just below the target of six. The master trainers then led a national workshop di Bogor, Indonesia, held from 5 to 10 July 2026, attended by 47 participants. Then, a regional workshop di Kuala Lumpur Malaysia, hosted by Universiti Teknologi Malaysia (UTM), held on 26 August to September 1st 2026, attended by 25 participants. Because Hanoi workshop cannot be proceeded, Vietnamese participants jointed the Kuala Lumpur event. Together the two workshops reached more than 60 participants that meet the project target.

Proficiency and effectiveness of the workshop was evaluated using Kirkpatrick's model, Hake normalised gain and Cohen's effect sized. Across 44 participants with matched assessment, self-assessed understanding rose from 3.47 to 4.15 on a five-point scale, a normalised gain of 0.445 (*p* < 0.001; *d*z = 0.94), and the proportion rated of proficient double from 31.8 % to 63.6 % from both workshops. The two produced statistically indistinguishable raw gains (+0.69 in Bogor and +0.67 in Kuala Lumpur) with no detectable heterogeneity, confirming that the programme performed consistently. All seven curriculum topics improved the participants knowledge significantly, and provides further evidence of The SciBUSP workshop's effectiveness, particularly in strengthening participants' knowledge, practical competencies, and self-reported readiness to apply SciBUPS concept and tool in their future urban planning activities.

2. Objectives

The overall aim of this project was to implement a comprehensive capacity-building programme that empowers early careers, to manage and apply Big Earth Data through training workshops and collaborative projects, effectively through the SciBUSP initiative. The specific objective;

a. To enhance the capacity of the early careers from Southeast Asia, particularly Indonesia, Malaysia and Vietnam, to serve as Master trainers of the SCiBUSP initiative; and
b. To promote SciBUSP initiative among stakeholders, especially early – careers professionals within Southeast Asia in support SDG 11

3. Outputs, Outcomes and Impacts

Table 1. Outputs, outcomes, impacts

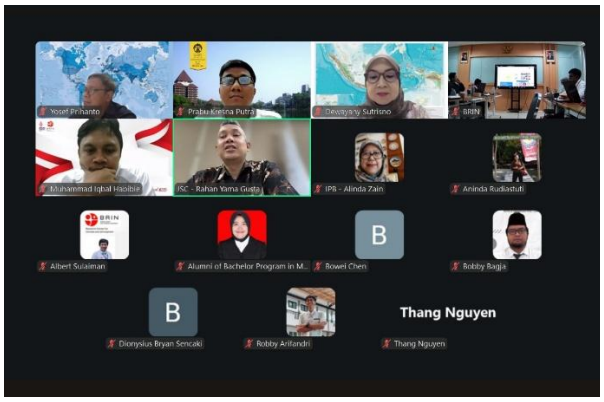
Level	No.	Item	Indicator	Target (time/ Participants)	Achievement (time/ Participants)	Status	Means of verification
	Preparation						
Output	1	Focus group discussions	Number of FGDs held	1	3	**Achieved**	3 Nov 2025, 9 Jan 2026, 5 Mar 2026; photos, record of attendance
	2	Kick-off meeting	Number of Participants	30	35	**Achieved**	3 November 2025, hybrid format; record of attendance
	Workshops						
	3	Training of Trainers, Jakarta	Number of Participants	20	25	**Achieved**	13–19 April 2026; attendance records
	4	Certified Master Trainers	Number of persons	6	5	**Not achieved**	Master Trainer certificate
	5	National workshop, Bogor	Number of Participants	20	47	**Achieved**	5–10 July 2026; attendance records
	6	Regional workshop, Kuala Lumpur (UTM)	Number of Participants	20	24	**Achieved**	26 August – 1 September 2026; attendance records
	7	Early-career professionals trained (Bogor and Kuala Lumpur)	Total participants	60	60	**Achieved**	Combined attendance records of the two workshops
	SciBUSP Prototype						
	8	SciBUSP prototype	Prototype operational and validated	1	1	**Achieved**	Prototype URL; or https://scibusp-rtm.tail6bc308.ts.net/ Copy right certificate
	9	Training modules, guidelines and case studies	Set of materials	1	1	**Achieved**	Appendix-2

Level	No.	Item	Indicator	Target (time/ Participants)	Achievement (time/ Participants)	Status	Means of verification
	10	Open-access data repository	Repository operational	1	1	**Achieved**	https://rin.brin.go.id
	11	Project report	Number of reports	1	1	**Achieved**	Final report to APN
	12	International publication	Number of publications	1		**In progress**	Submit to APN
Outcome	13	Participants' understanding improvement	Pre-pots composite's gain (pooled)		0.347-0.415	**Achieved**	44 matched participants; Hake method
	14	Participants showing improvement	% of participants improving (pooled)		72.7%	**Achieved**	32 of 44 participants
	15	Participants reaching proficiency	% with a final score of 4.0 or above (pooled)		63.6%	**Slightly Not achieved**	From pooled training, Malaysia achieved, Indonesia not achieved
	16	Practical competence with the SciBUSP Toolkit	% proficient on the practical subscale		52.3%	**Achieved**	Bogor 35.7%; Kuala Lumpur 81.3%
	17	Participant satisfaction	% agreeing (score of 4 or above) (pooled)		85.1%	**Achieved**	Average of 51 post-assessment respondents
	18	Intention to apply the knowledge	% agreeing (pooled)		92.2%	**Recorded**	Highest-rated item in the evaluation
Impact	19	Evidence-based planning practice	Spatial plans drawing on SciBUSP outputs			**Not yet measured**	Follow-up survey six months after the final workshop

4. Key facts/figures

3 focus group discussions and 1 hybrid kick-off meeting with 35 participants informed the co-design of the SciBUSP toolkit and assessment instruments

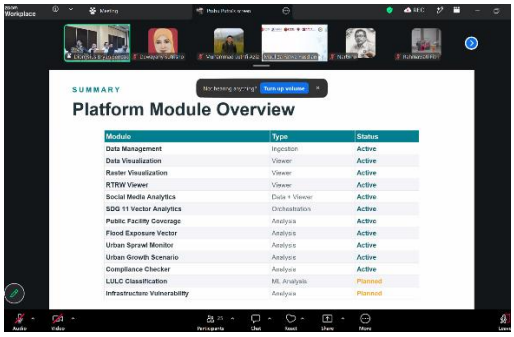




1st Focus group discussion held on November 3th 2025 in BRIN office Cibinong, combining both in-person and virtual, with total 16 participants. The meeting focused on urban development projects using satellite data and socioeconomic information, with presentations on development patterns, sustainability challenges, and sustainable urban development concepts in Indonesia. Researchers discussed various applications of Earth observation data for sustainable development goals, including monitoring environmental changes and supporting urban planning. The participants explored data collection challenges, particularly regarding social media data access and restrictions, and discussed the development of the SciBUSP platform with emphasis on climate change considerations and potential case studies. Besides that, a project using the rapid method to analyze urban development using real-time satellite data and socioeconomic information. Professor Dewayany presented results showing the development patterns of Tangerang and surrounding cities from 1998 to 2024, highlighting population changes and infrastructure developments. The project aims to equip young scientists with skills to use big data in urban planning through workshops with Malaysia, Vietnam, and China, targeting the training of 6 master trainers and 60 early career professionals.

Participants:

1. Dr. Ir. Alinda F. M. Zain, M.Si, IPB university
2. Rama Yahan Gusta (Jakarta Smart City)
3. Dr. Albertus Sulaiman, BRIN
4. Dewayany Sutrisno, BRIN
5. Bowei Chen, Aerospace Information Research Institute Chinese Academy of Sciences
6. Nguyen Ngoc Thang, Institute of Geography, Vietnam Academy of Science and Technology
7. Suzanna Binti Noor Azmy, Universiti Teknologi Malaysia
1. Prabu Kresna Putra, BRIN
2. Aninda Wisaksanti Rudiastuti, BRIN
3. Boby Bagya Pratama, BRIN
4. Ayub Sugara, Universitas Bengkulu
5. Robby Arifandri, NTU
6. Yosef Prihanto, BRIN
7. Dionysius Bryan Sencaki, BRIN
8. Hari Prayogi, BRIN
9. M.Iqbal Habibie, BRIN





2nd FGD was conducted on 19 february 2026 at the BRIN Office, Cibinong, Bogor, Indonesia. A total of approximately 21 participants. The small group of FGD was discussed regarding the result of Kick-off meeting, the planning to strengthen the SciBUSP methodology, The criatreia for master trainers and workshop participants.

Participants

1. Prof. Dr. Dewayany Sutrisno, BRIN
2. Boby Bagja Pratama, BRIN
3. Prabu Kresna Putra, BRIN
4. Dionysius Bryan Sencaki, BRIN Hari Prayogi, S.Si., M.Si, BRIN
5. Aninda Wisaksanti Rudiastuti, S.Pi., BRIN
6. Dr. Yosef Prihanto
7. Dr. Heru Santoso
8. Robby Arifandri
9. Eka Dewiki
10. Yulia Suliwowati
11. Yeli Sarvina
12. Aulia
13. Nguyen Ngoc Thang
14. Bowei Chen
15. Unggul
16. Narulita
17. Yudhi Fang
18. Nartono
19. Sriyono
20. Suci
21. Eko Hardito




The 3rd FGD was conducted on 5 March 2026 at the BRIN Office, Cibinong, Bogor, Indonesia, and was organized in a hybrid format, combining both in-person and virtual participation. A total of approximately 10 participants . The team discussed accessing and using SDG SAT data for their urban sprawl research project. Bowei explained the process for submitting a proposal to access the data, which requires a short proposal and geo-shape files for the study regions. They discussed the resolution of SDG SAT data, which is 10-meter after pan sharpening, and the need to convert NDVI values to reflectance. The team considered using alternative data sources like land use/land cover products for more efficient urban sprawl detection. Bowei recommended exploring the PLUS model for future urban sprawl predictions, though Markov

chain models were also discussed. The group also addressed challenges with collecting social media data due to changes in Twitter's policies, with Bowei suggesting streaming recent data as a potential workaround. The team also reviewed a web-based system prototype developed by Prabu's team for predicting urban sprawl, with Professor Bowei offering feedback on improving the model complexity while maintaining a web-friendly interface.

Participants

1. Prof. Dr. Dewayany Sutrisno, BRIN
2. Boby Bagja Pratama, BRIN
3. Prabu Kresna Putra, BRIN
4. Dionysius Bryan Sencaki, BRIN
5. Hari Prayogi, S.Si., M.Si, BRIN
6. Aninda Wisaksanti Rudiastuti, S.Pi., National University of Singapore
7. Ayub Sugara, Universitas Bengkulu
8. Bowei Chen, Aerospace Information Research Institute Chinese Academy of Sciences
9. Dr. Albertus Sulaiman
10. Dr. Ati Rahadiati







Kick -off Meeting was conducted on Monday, 7 january 2026 in Bogor, Indonesia, and was organized in a hybrid format, combining both in-person and virtual participation. A total of approximately 35 participants attended the meeting, including 23 participants onsite and 12 participants online. The meeting focused on various aspects of urban spatial planning and the application of remote sensing technology for sustainable development, with presentations covering data sharing systems, environmental assessments, and challenges in different regions including China, Vietnam, and Malaysia. Dr. Chen presented on the SDG1 Open Science Project, highlighting their global data sharing system that provides access to satellite imagery and other data for research purposes. He showcased various applications of their technology, including urban development monitoring and environmental assessments in different regions,

including China. Thang Nguyen then gave a brief overview of how remote sensing technologies can support sustainable urban spatial planning in Vietnam, focusing on applications like urban land use mapping, flood risk assessment, and urban heat island analysis. Participants discussed the implementation of science-based results from remote sensing to improve social well-being, addressing issues like traffic congestion, urban sprawl, and loss of green space. The conversation concluded with discussions on smart city concepts, urban water management in the Greater Jakarta area, and the need for integrated spatial planning and research collaboration between universities and government agencies.

Participants

Offline

1. Dr.Rachman Kurniawan
2. Dr. Albertus Sulaiman
3. M. Iqbal Habibie, Ph.D
4. Oni Bibin Bintoro, Ph.D
5. Dr. Alinda FM. Zain
6. Dr. Janthy T. Hidayat
7. Dr. Agustan
8. Dr. Arifin Rudyanto
9. Dr. Asep Karsidi
10. Rahan Yama Gusta
11. Prof. Dr. Johnson L. Gaol
12. Prof. Supriatna
13. Dr. Hayati Sari Hasibuan Meilia DR
14. Martasuganda
15. Fahri Ramadhani
16. Dr. Susetyo
17. Dr. Budi Heru Santosa
18. Aninda Wicaksanti
19. Prabu Kresna Putra
20. D. Bryan Sencaki
21. Hari Prayogi
22. Boby Bagja Pratama
23. Prof. Dr. Dewayany S.

Online

1. Dr. Yosef Prihanto
2. Dr.-Ing. Widodo Setiyo Pranowo
3. Ayub Sugara
4. Dr. Suzanna binti Noorazmi
5. Nguyen Ngoc Thanh
6. Bowei Chen, PhD
7. Tanjil Sowgat PhD
8. Dr. Sharina Tariq
9. Robby Arifandri,
10. Dr. Laras tursilawati
11. Dr. Ati Rahadiati
12. Dr. Bono Pranoto

20 early-career professionals from Indonesia, Malaysia and China attended the Training of Trainers in Jakarta (13–19 April 2026), of whom 5 qualified as certified Master Trainers










The ToT was held in Jakarta from 13 to 19 April 2026 and was attended by 25 participants from Indonesia, Malaysia, Vietnam, Bangladesh and China together with 3 mentors and resource persons from BRIN, Chinese Academy of Science, and Bangladesh. The ToT workshop was also held in hybrid format. All five phases of the curriculum were delivered. Participants conducted pilot tests of the toolkit on Jakarta Mega city and prepared action plans for national training. The ToT demonstrated the SciBUSP platform's capabilities, including data management, visualization, and analysis modules for urban planning. The presentations triggered discussions and test about the SciBUSP curucullum and the method underneed, and the importance of creating user-friendly interfaces for city planners and decision-makers. Participants also discussed technical challenges in land use classification, particularly in tropical regions with complex landscapes and high cloud cover, emphasizing the need for robust models that can work across different climates and environments. On completion, 5 participants met the requirements for certification as SciBUSP Master Trainers, against a target of at least six

Participants

Offline

1. Dr.Rachman Kurniawan
2. Dr. Albertus Sulaiman
3. M. Iqbal Habibie, Ph.D
4. Oni Bibin Bintoro, Ph.D
5. Dr. Agustan
6. Dr. Asep Karsidi
7. Dr. Laju Gandharum
8. Dr. Iksal Yanuarsa

Online

1. Bowei Chen, PhD
2. Dr. Yosef Prihanto
3. Ayub Sugara
4. Dr. Suzanna binti Noorazmi
5. Nguyen Ngoc Thanh

9. Dr. M.Iqbal Habibie
10. Iwan Setiawan
11. Prabu Kresna Putra
12. Dionysius Bryan Sencaki
13. Hari Prayogi
14. Boby Bagja Pratama
15. Tanjil Sowgat PhD
16. Rizki amalia
17. Ati Rahadiati
18. Syed Ahmed Reza
19. Wei chee cheah
20. Prof.Dr. Dewayany Sutrisno

5 qualified as certified Master Trainers

Appendix-1

60 early-career professionals trained across two workshops — 42 in Bogor, Indonesia (5–10 July 2026) and 18 in Kuala Lumpur, Malaysia (26 August – 1 September 2026)

National workshop;



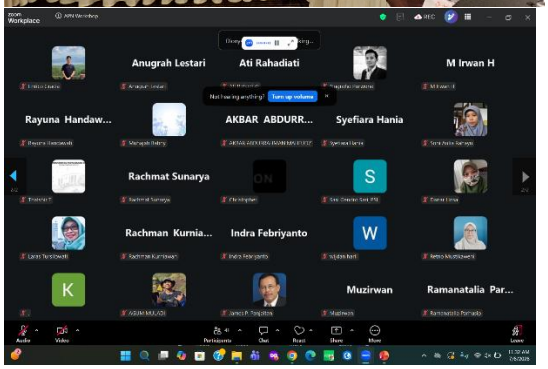












At least 42 Early Careers either online or off line, were participated in the National workshops were led by the Master Trainers (5 persons) with support from the core team and national partners. The event was held on Bogor from 5 To 10 July 2026. The training programme provided participants with a combination of foundational theoretical concepts, hands-on exercises in modelling methodologies, and practical experience in applying the SciBUSP Toolkit to spatial planning and analysis Pre- and post-training assessments were administered to all participants to evaluate improvements in their understanding, practical competencies, and ability to apply the SciBUSP approach

Participants

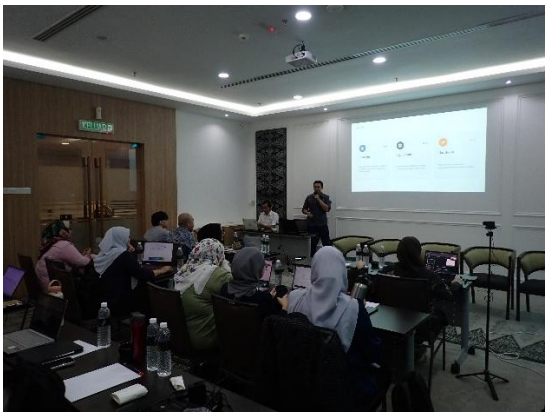
1. Mauliza Fatwa Yusdian
2. Yosmaniar
3. Meylis safriani
4. Muhajah Babny
5. Rayuna Handawati
6. Christopher Aurel
7. Delfy Lensari
8. Wijdan Khairul Tsany Harli
9. Nugroho Purwono
10. James Parlindungan Panjaitan
11. Agum Muladi
12. Laras Toersilowati
13. Reni Srimulyaningsih
14. Muhammad Luthfi Aziz
15. Sasi Gendro Sari
25. Sunartono
26. Mochamad Irwan Hariyono
27. Muzirwan
28. Mega Dwi Jayanti
29. Janthy T Hidayat
30. Luthfiyyah Dzakiyyah W
31. Alinda FM Zain
32. Bono Pranoto
33. Muhammad Thafsir Triansha
34. Raffy Bagus Prayudha
35. Ryan Sabian
36. Safnita Andriani Rambe
37. Zilda Dona Okta Permata
38. Dipo Yudharana
39. Nico Anatoly

16. Enrico Gracia
17. Hari Prayogi
18. Yuni
19. Akbar Abdurrahman Mahfudz
20. Rahmawati Fitri
21. Syefiara Hania
22. D. Bryan Sencaki
23. Prabu K. Putra
24. Boby Bagja Pratama
40. Siti Arfah
41. Feri Nugroho
42. Lia Chaerani
43. Septina Marryanti P
44. Yosef Prihanto
45. Alfi Indriany Putri
46. Ayub Sugara
47. Dewayany Sutrisno

Regional workshop















Following the national workshop, a regional workshop was held in Kualalumpur Malaysia, on August 26th to September 1st 2026, host by University Technology Malaysia (UTM). 24 people were participated., with 18 early careers active in the workshop. Since the Hanoi, Vietnam workshop can be implemented due certain circumstances, the Vietnamese participants were actively participate in the Kuala Lumpur workshop, either online or offline. As in Bogor workshop, the training programme provided participants with a combination of foundational theoretical concepts, hands-on exercises in modelling methodologies, and practical experience in applying the SciBUSP Toolkit to spatial planning and analysis. Pre- and post-training assessments also were administered to all participants to evaluate improvements in their understanding, practical competencies, and ability to apply the SciBUSP approach

Participants

1. Rizaludin Mahmud
2. Muhamad Solehin Fitry Bin Rosley
3. Ashleza Binti Ahmad
4. Dionysius Bryan Sencaki
5. Sarah Ahmad
6. Hari Prayogi
7. Nadzirah Hosen
8. Daeng Muhammad Fatwa Bin Mohd Mushtri
9. Janatun Naim Yusof
10. Syahiirah Salleh
11. Suzanna Noor Azmy
12. Cheah Wei Cheah
13. Nurul Nadiah binti Yahya
14. Nurul Amalin Fatihah Kamarul Zaman
15. Kugan A/L Raju
16. Noordyana Hassan
17. Thang Nguyen Ngoc
18. Bui Thi Thanh Huong
19. Nazarin Ezzaty Binti Mohd Najib
20. Prabu Kresna {utra
21. Boby Bagja Pratama
22. Ayub Sugara
23. Prof. Dr. Mazlan Bin Hashim
24. Prof.Dr Dewayany Sutrisno

For dissemination of the project, 3 person attend the 6th Forum for Big Data For Sustainable Development Goals, in Beijing China, September 6th 70 8th 2026













Achievement of the workshops (Bogor, Indonesia and Kuala Lumpur, Malaysia):

1. **44 participants with matched pre- and post-assessments raised their self-assessed understanding from 3.47 to 4.15 on a five-point scale — a class-average normalised gain of 0.445 ($p < 0.001$; $dz = 0.94$, a large effect)**
2. **72.7% of participants improved, and the proportion rated proficient (score of 4.0 or above) doubled from 31.8% to 63.6%**

Table 2. Achievement of the SciBUSP workshop analysis

INDICATOR	THRESHOLD	BOGOR	STATE	KUALA LUMPUR	STATE	POOLED	STATE
n (Matched Pairs)	—	28		16		44	Matching participants only
Understanding improvement	—	3.22 to 3.91		3.89 to 4.56		3.47 to 4.15	Improved
Scale Attainment	—	64.5% to 78.3%		77.9% to 91.3%		69.4% to 83.0%	improved
Normalised Gain ⟨*G*⟩	≥ 0.30	0.388	achieved	0.605	achieved	0.445	achieved
Paired *T* Test (*P*)	< .05	.0001	achieved	.0005	achieved	< .0001	achieved
Cohen D_z	≥ 0.80	0.87	achieved	1.11	achieved	0.94	achieved
Participants Improved	≥ 70%	67.9%	Not achieved	81.3%	achieved	72.7%	achieved
Proficient At Post-Assessment	≥ 75%	57.1%	Not achieved	75.0%	achieved	63.6%	Not achieved
Reaction Responses ≥ 4	≥ 80%	78.2%	Not achieved	97.8%	achieved	85.1%	achieved

All 7 curriculum topics recorded statistically significant gains, with the largest improvements in the practical application of the SciBUSP toolkit

No.	Curriculum topic	Mean before	Mean after	Gain	Normalised gain ⟨g⟩	Status
1	SDG 11 and sustainable urban planning	3.750	4.364	0.614	0.491	**Achieved**
2	Urban heat island and climate change	3.795	4.318	0.523	0.434	**Achieved**
3	GIS for urban analysis	3.795	4.409	0.614	0.509	**Achieved**
4	Machine learning for urban applications	3.295	4.091	0.795	0.467	**Achieved**
5	Deep learning for urban analysis	3.295	4.000	0.705	0.413	**Achieved**
6	SciBUSP Toolkit — concepts and workflow	3.341	3.955	0.614	0.370	**Achieved**
7	SciBUSP Toolkit — practical application	3.000	3.909	0.909	0.455	Achieved
	All seven topics (overall scale)	**3.468**	**4.149**	**0.682**	**0.445**	**7 of 7 topics achieved**

The majority of the 51 post-assessment respondents were satisfied with the programme, and 92.2% intended to apply the knowledge in their own planning work — the highest-rated item in the evaluation

Item	Statement presented to participants	Bogor, Indonesia (n = 33)	Kuala Lumpur, Malaysia (n = 18)	Pooled (n = 51)
		Agreement (%)	Agreement (%)	Agreement (%)
1	The workshop content met my needs.	78.8	100.0	86.3
2	The speakers delivered the material clearly.	84.8	100.0	90.2
3	The practical sessions improved my skills.	81.8	100.0	88.2
4	The workshop duration was appropriate.	57.6	88.9	68.6
5	I intend to apply this knowledge in my work or research.	87.9	100.0	92.2
Scale	**Composite reaction score (mean of C1–C5)**	**57.6**	**100.0**	**72.5**

1 SciBUSP prototype developed and validated, 1 set of training modules, guidelines and case studies, and 1 open-access data repository established.

Link SciBUSP: http://10.6.0.26:8010/ (From BRIN Network) or https://scibusp-rtm.tail6bc308.ts.net/ (From Public Network), Copyright registration: ©2026 National Research and Innovation Agency (BRIN). All rights reserved.
Link Dataset: https://rin.brin.go.id
Module: Attachement-2
Guidance: Attachment-3

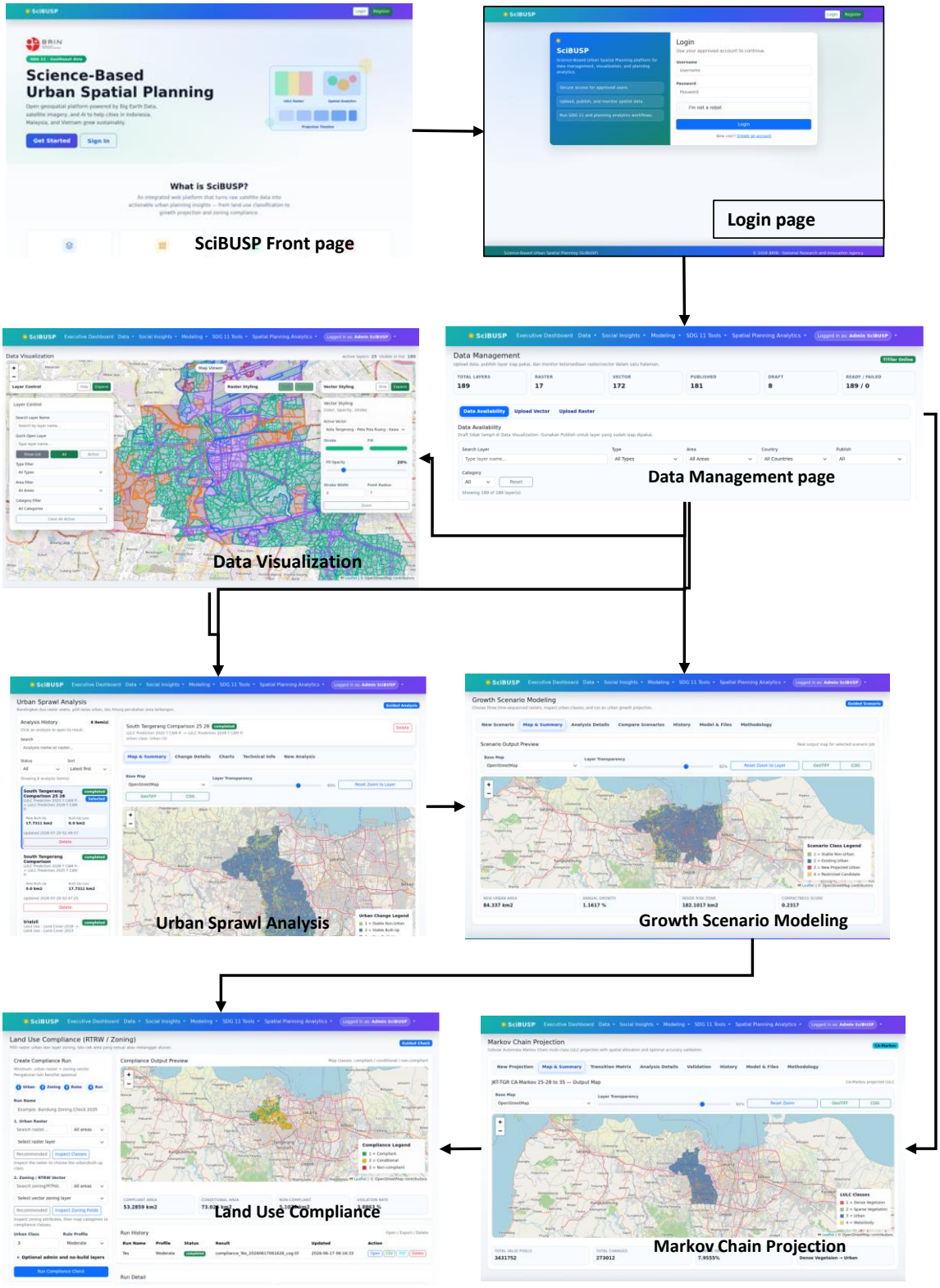


Figure 1. SciBUPS Analysis Processing

1 peer-reviewed article submitted to the APN Science Bulletin

5. Publications

Sutrisno, D., Putra, P. K., Pratama, B. B., Sencaki, D. B., Prayogi, H., Sugara, A., Chen, B., Nguyen, N. T., & Noorazmi, S. (2026). Evaluating science-based urban spatial planning (SciBUSP) capacity building for SDG 11: A cross-site evaluation in Indonesia and Malaysia workshops. APN Science Bulletin.

6. Media reports, videos and other digital content

Refer to Section 4. Key facts/figures

7. Pull quotes

Dr Dewayany Sutrisno, Project Leader, BRIN / Indonesian Society for Remote Sensing
"The exchange of knowledge and experiences from different countries has clearly demonstrated that no single institution or country can address these complex challenges alone. Throughout our discussions, we have explored how Big Earth Data, geospatial technologies, artificial intelligence and evidence-based spatial planning can contribute to addressing some of the most pressing urban challenges of our time. The Science-Based Urban Spatial Planning (SciBUSP) initiative represents more than a research project. We hope to strengthen the skill and knowledge for the early career and young professionals to become leaders in applying such technology, especially to support SDG 11."

Assoc. Prof. Suzanna Noor Azmi, Universiti Teknologi Malaysia, host of the regional workshop
"Hosting the regional workshop allowed our participants to work alongside colleagues from Indonesia and Vietnam on the same urban problems. The cascade model worked: the Master Trainers trained in Jakarta were the ones leading the sessions in Kuala Lumpur, which is exactly the sustainability we had hoped for."

Participants (Malaysia)
"Before the workshop, I used satellite imagery mainly to produce maps. The SciBUSP toolkit gave me a way to link those maps to SDG 11 indicators so that what I present to my agency is no longer a picture but an argument."

Participants (Vietnam)
"Organize in different country, enabling cultural exchange. Please held it in Vietnam"

Participants (Indonesia)
"This programme should be strengthened and expanded in future, as it is greatly needed by skilled practitioners, bearing as it does directly on the decisions taken by city and regional governments"

8. Acknowledgements

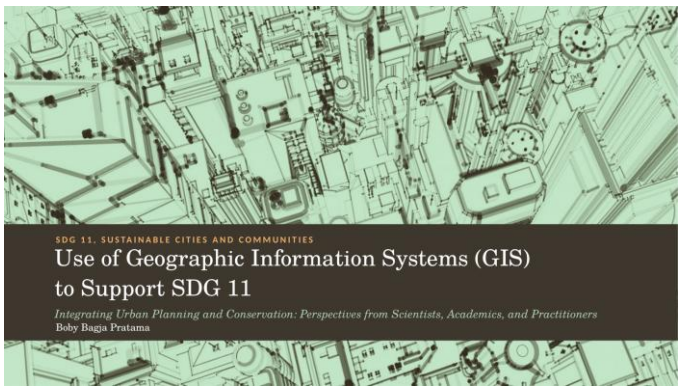
This project is based on work supported by the Asia-Pacific Network for Global Change Research (APN) under Grant No. CBA2025-02SY-Sutrisno

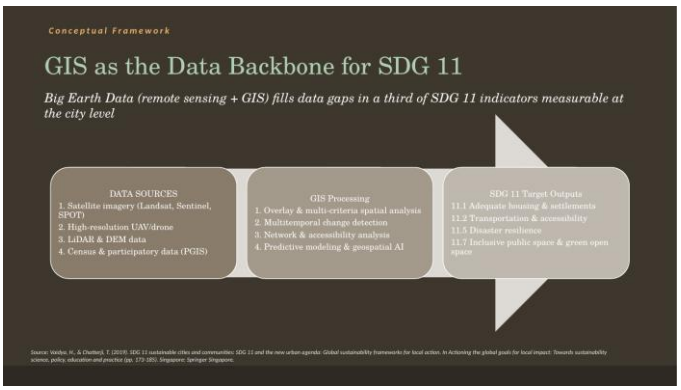
9. Appendices

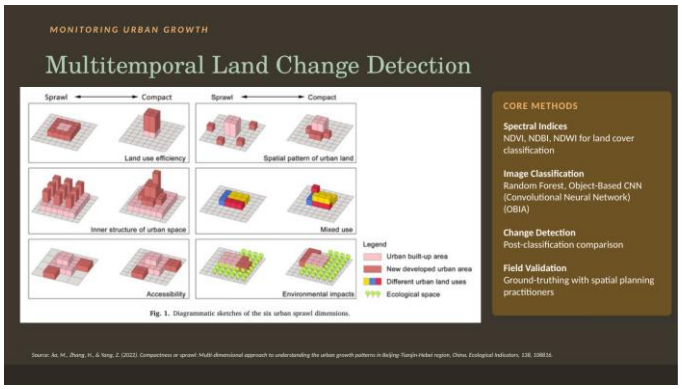
Appendix-1: Master trainers certificates

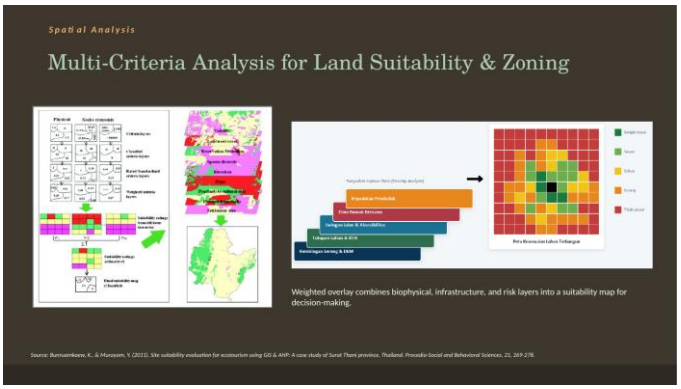


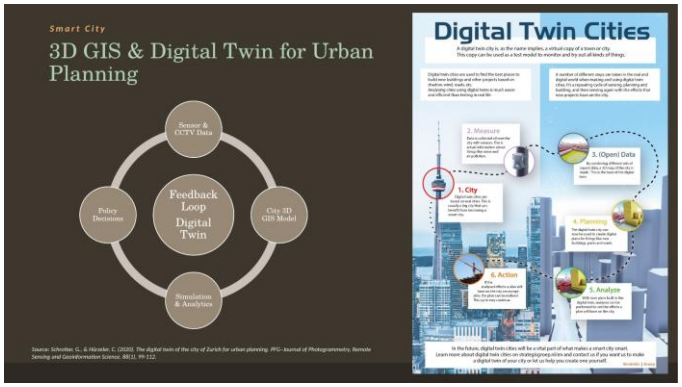
Appendix-2. SciBUSP Modules

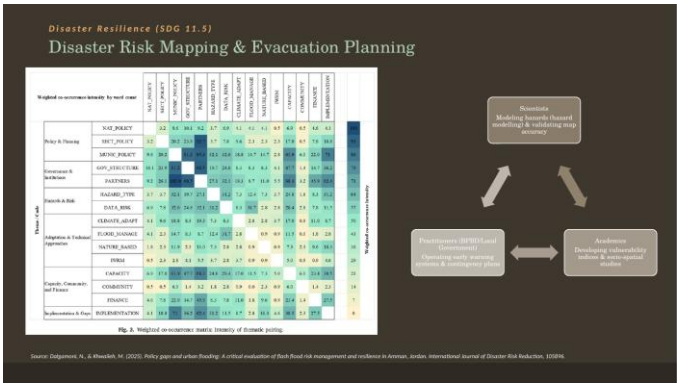


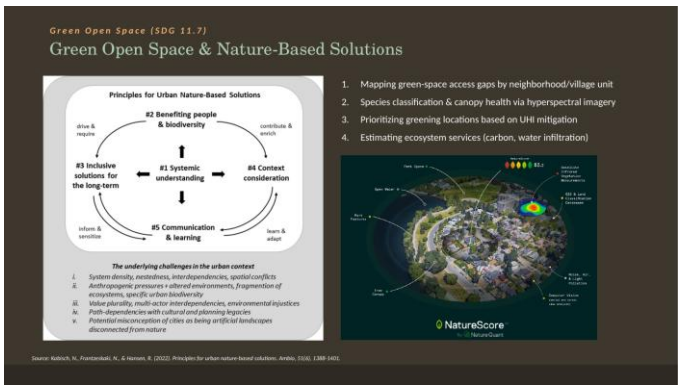


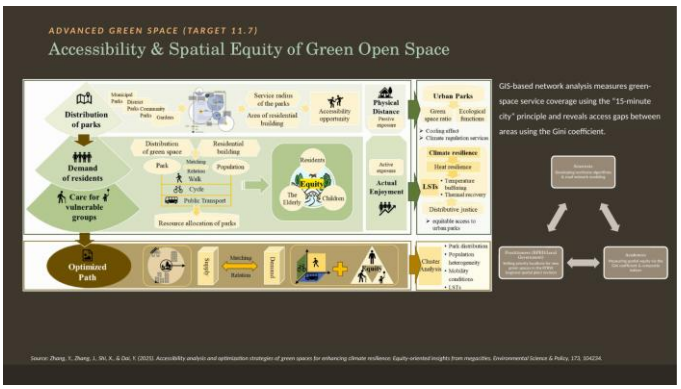






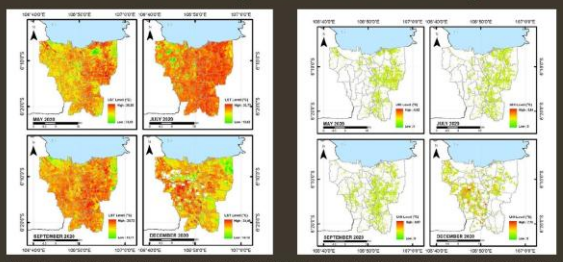






URBAN HEAT ISLAND RESEARCH (TARGET 11.6/11.7)

Urban Heat Island Monitoring via Thermal Remote Sensing



Extracting Land Surface Temperature (LST) from Landsat/Sentinel/ECOSTRESS thermal bands reveals Surface UHI (SUHI) patterns and their correlation with vegetation cover & building density.

Source: Saputra, A., Ibrahim, M. H., Shofiyun, S., Sathuddin, A., & Furoida, R. (2022, February). Assessing urban heat island in Jakarta, Indonesia during the pandemic of Covid-19. In IOP Conference Series: Earth and Environmental Science (Vol. 986, No. 1, p. 012069). IOP Publishing.

MARINE SPATIAL PLANNING

GIS for Marine Spatial Planning in Coastal Cities



GEOSPATIAL TECHNOLOGY FOR MSP

1. Multispectral remote sensing for bathymetry & water quality
2. Acoustic telemetry & vessel tracking (AIS/VMS)
3. Spatial use-conflict modeling (use-conflict mapping)
4. Participatory GIS with fishers & coastal communities

Major coastal cities are beginning to integrate marine zones into spatial planning, balancing ports, fisheries, and conservation.

Source: Smith, H. D., Maes, F., Stojanovic, T. A., & Ballinger, R. C. (2011). The integration of land and marine spatial planning. Journal of Coastal Conservation, 15(2), 291-303.

CONSERVATION: PROTECTED AREAS & PARTICIPATORY GIS

Spatial & Participatory Conservation Monitoring



Kegiatan Survey dan Konsultasi Masyarakat untuk penentuan wilayah adat dalam rangka Identifikasi Potensi OECMs di Goron Kabupaten Seram Bagian Timur

VALUE OF PARTICIPATORY GIS (PGIS)

Direct Use Value
Fisheries, marine tourism, non-timber forest products

Indirect Use Value
Ecosystem services: coastal protection, carbon sequestration

Non-Use Value (Existence)
Cultural, spiritual, and heritage significance for local communities

Combining satellite data with local knowledge (participatory GIS) strengthens the legitimacy and effectiveness of conservation areas.

RESEARCH FRONTIER

Next-Gen Geospatial Technology

Geospatial Foundation Models
Pre-trained multi-task AI models for building detection, land cover, & cross-domain SDG monitoring

Cloud Geoprocessing
Platforms like Google Earth Engine enable planet-scale time-series analysis without local infrastructure

UAV & Photogrammetry
Ultra-high-resolution data acquisition for fast & low-cost local monitoring

GIS-Connected IoT (Internet of Things) Sensors
Integrating real-time air quality, water, and noise data into city spatial systems

Source: Hochmair, H. H., Juhász, L., & Li, H. (2025). Advancing AI-driven geospatial analysis and data generation: methods, applications and future directions. ISPRS International Journal of Geo-Information, 14(2), 56.

Closing

Conclusion

Key Points

1. GIS & Big Earth Data fill data gaps in SDG 11 indicators at the city level
2. Modern urban planning can be supported by integrating 3D GIS, Multi-Criteria Decision Analysis, and digital twins.
3. GIS-based green-space accessibility analysis & UHI monitoring strengthen policies for cooler, more equitable cities.
4. Marine spatial planning extends city spatial planning coverage to coastal & marine areas.
5. Collaboration among scientists, academics, and practitioners is a prerequisite for successful implementation.

BUILD UP ARE PREDICTION MODEL

Dionysius Bryan Sencaki, S.T., M.Env
Hari Prayogi, S.Si., M.Si.

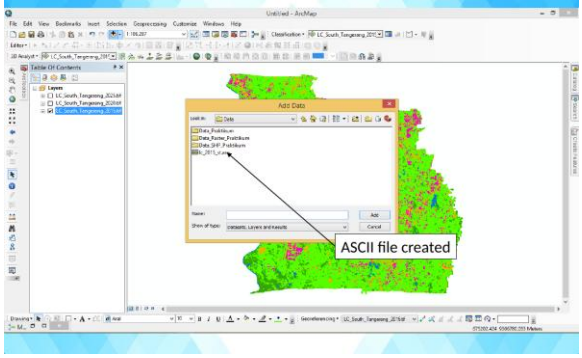
Kuala Lumpur, 28 July 2026



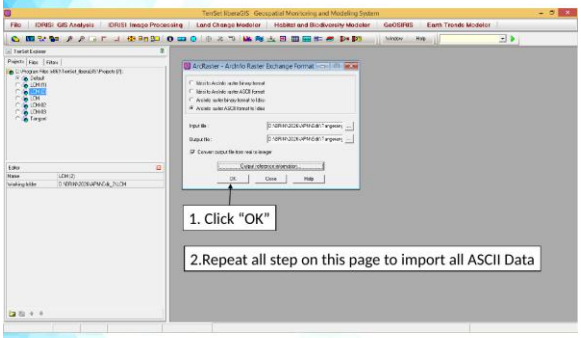
OUTLINE HANDS ON

1. Convert TIFF to ASCII
2. Import Data ASCII
3. Setting Category Data
4. Edit Atribute Data
5. Prediction Model
6. Accuracy Model
7. Export Data to ASCII
8. Convert ASCII to TIFF

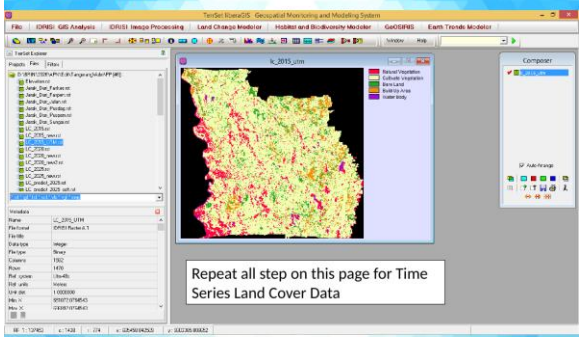
1. CONVERT TIFF TO ASCII



2. IMPORT DATA ASCII IN TERRSET



3. SETTING CATEGORY DATA



4. EDIT ATRIBUTE DATA

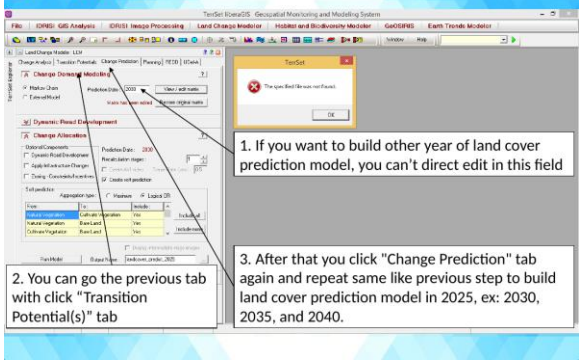


Distance To Bussines
Distance To Education
Distance To Government
Distance To Healtcare
Slope

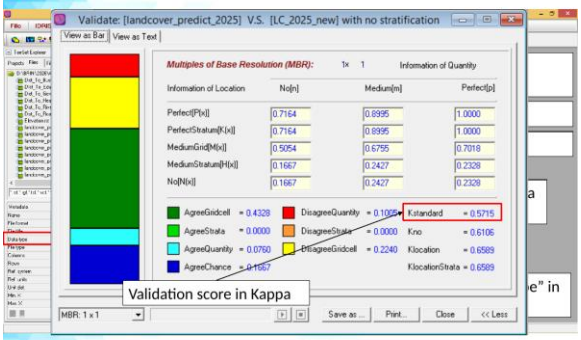
Distance To Road

Elevation

5. PREDICTION MODEL



6. ACCURACY MODEL



SCIENCE • BIG EARTH DATA • SDG 11

Built-up Area Prediction Model Supporting SDG 11

A Case Study of Greater Tangerang - Indonesia

Strengthening Science- and Big Earth Data-Based Capacity for Sustainable City Planning to Help Achieve SDG 11

PRESENTATION AGENDA

What We Will Cover

01 **Background & Urgency**
Urbanization and city planning challenges in Indonesia

02 **SDG 11 & Built-up Area**
How city growth connects to global targets

03 **Model, Methodology & Software**
Modeling approaches and software strengths and weaknesses

04 **Case Study: Greater Tangerang**
Built-up area trends in Tangerang Regency, Tangerang City, and South Tangerang City

05 **Capacity Building & Recommendations**
Strategies to support sustainable city planning

2

BACKGROUND

Fast Urban Growth, Planning Left Behind

Indonesia's urban population is growing very fast, pushing built-up areas to expand — often uncontrolled and without accurate spatial data.

Traditional city planning struggles to anticipate the direction and speed of urban growth. This raises the risk of uncontrolled land conversion, uneven density, and pressure on infrastructure and the environment.

56%+
of Indonesians live in urban areas

1.9%
annual growth rate of built-up land

200+
cities/regencies need up-to-date spatial data

Without a reliable prediction tool, spatial policy tends to react to problems instead of preventing them.

3

SDG 11

Inclusive, Safe, Resilient, and Sustainable Cities and Settlements

SDG 11
Sustainable Cities and Communities

One of the 17 Sustainable Development Goals (SDGs), focused on urban living spaces.

11.1 Safe, decent, and affordable housing

11.3 Inclusive, sustainable urbanization and participatory planning capacity

11.6 Lower per-capita environmental impact of cities

11.a Integrated planning across urban, peri-urban, and rural areas

About SDG 11:
A global program to make cities and settlements inclusive, safe, resilient, and sustainable. Its main focus areas include decent housing, accessible public transport, good spatial management, and protecting cultural heritage while reducing disaster risk.

4

DATA AND SDG 11

Built-up Area as a Key SDG 11 Indicator

Indicator 11.3.1 measures the ratio between the Land Consumption Rate and the Population Growth Rate — making built-up area data quantitative evidence of progress toward sustainable urbanization.

LCRPGR = LCR ÷ PGR

LCR: rate of built-up land expansion
PGR: rate of population growth

- ***Ratio ≈ 1*** — *city growth is balanced with population growth*
- ***Ratio > 1*** — *urban sprawl — land expands faster than population*
- ***Ratio < 1*** — *density rises, adding pressure on basic services*

A built-up area prediction model lets this indicator be calculated ahead of time — not just evaluating the past, but anticipating where cities will grow next, for more timely spatial planning decisions.

5

THE PROBLEM

Challenges in Data-Driven City Planning Today

Outdated Data
Spatial plans often lag behind actual conditions on the ground

Limited Spatial Coverage
Field surveys are costly and too slow to cover an entire region

Limited Analytical Capacity
Too few skilled staff and tools to process spatial-statistical data

Reactive Planning
Policies adjust after growth happens, instead of before

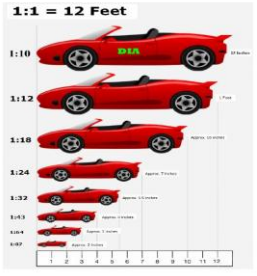
6

Model

A simplified representation of something real, built to make it easier to understand or analyze further.

Example Models:

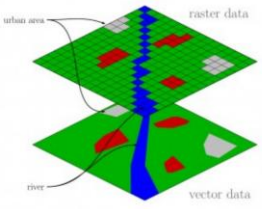




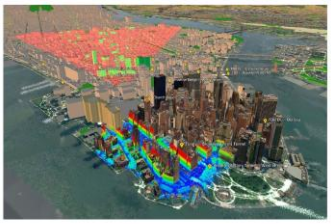
Source:
1. https://mediaindonesia.com/humaniora/789457/apa-itu-model-pengertian-fungsi-dan-contoh-praktis
2. https://jasnbandonsainarsitek.com/maket-arsitektur-miniatur-model-10
3. https://dragtanywhere.com/drag-racing-supplies/

Model

A way of representing a real-world phenomenon, so its objects or patterns can be studied and later used for problem-solving analysis.1)



2)



Source:
1. https://spasindomap.wixsite.com/spasindo/analisis-dan-pemodelanspasial#:~:text=Pemodelan%20spasial%20merupakan%20cara%20merepresentasikan%20dapat%20bermanfaat%20untuk%20penyelesaian%20masalah. % 20fenomena%20di%20dunia,tersebut%2C%20yang%20selanjutnya
2. https://equatorstudios.com/raster-vs-vector-data-formats-in-gis
3. https://www.linkedin.com/pulse/unveiling-power-3d-geospatial-modeling-santosh-kumar-bhoda.

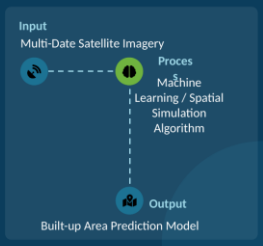
31

THE SOLUTION

What Is a Built-up Area Prediction Model?

A computational model that uses historical spatial data — satellite imagery, land cover, and population — to project where and how built-up land will expand in the future.

- Identifies locations at risk of land conversion
- Projects growth scenarios 5–20 years ahead
- Produces actionable spatial prediction maps



DATA SOURCES

Big Earth Data: The Foundation of the Prediction Model

Optical Satellite Imagery
Landsat, Sentinel-2 — medium resolution, long historical coverage

High-Resolution Imagery
SPOT, PlanetScope — detects fine building and infrastructure detail

Land Cover and Land Use Data
National thematic maps and global land cover products

Socio-Demographic Data
Census, population density, and mobility data

Infrastructure Data
Roads, power, and public facility networks as driving variables

Administrative and Policy Data
Spatial plans (RTRW), boundaries, and protected area status

METHODOLOGY

Workflow for Built-up Area Prediction Modeling

1. **Data Acquisition** — Collect multi-date satellite imagery and supporting data
2. **Pre-processing** — Geometric and radiometric correction, land cover classification
3. **Modeling** — Spatial simulation (CA-Markov) or machine learning
4. **Validation** — Test accuracy against actual observed data
5. **Prediction & Visualization** — Maps of future built-up area scenarios

TECHNICAL APPROACHES

Comparing Spatial Modeling Approaches

Approach	How It Works	Main Strength
Cellular Automata–Markov Chain	Simulates land-cell transitions based on historical probability	Captures local spatial patterns explicitly
Machine Learning (Random Forest, XGBoost)	Learns patterns from many growth-driving variables	Accurate for complex, non-linear relationships
Deep Learning (CNN/LSTM)	Automatically extracts image features and time patterns	Excels with high-resolution imagery and time-series data
Agent-Based Model	Simulates the behavior of actors such as households and developers	Explains the mechanisms behind growth patterns

Markov Chain
Learns transition probabilities between land classes from historical raster data to estimate how much change will occur.

Cellular Automata
Uses spatial neighborhood rules between pixels to determine where change is most likely to occur.

SOFTWARE

Software Options for Prediction Modeling

QGIS + MOLUSCE
Open-source, with a built-in CA-Markov plugin

TerrSet / IDRISI
A dedicated Land Change Modeler for land prediction

ArcGIS Pro
An enterprise-grade geoprocessing ecosystem

Google Earth Engine
Cloud-based Big Earth Data processing

R / Python
Flexible programming for ML and deep learning

ENVI
Satellite image pre-processing and classification

SOFTWARE COMPARISON

Strengths and Weaknesses of Each Tool

Software	Strengths	Weaknesses
QGIS + MOLUSCE	Free and open-source; CA-Markov/ANN ready to use in one plugin	No scenario or constraint factors (business-as-usual projection only); slow with high-resolution data
TerrSet / IDRISI (Land Change Modeler)	A dedicated module for land change prediction; supports scenarios and policy constraints	Paid, with a relatively high license cost; steep learning curve and less familiar to local agencies
ArcGIS Pro	Full geoprocessing suite; integrates easily with agency spatial-plan databases; enterprise support	Expensive annual license; advanced prediction modeling needs extra extensions
Google Earth Engine	Direct cloud access to Landsat/Sentinel archives; processes large-scale data without local downloads	Requires programming skills; no native CA-Markov/ABM; depends on an internet connection
R / Python	Flexible for complex ML/deep learning; open-source with a reproducible workflow	Requires coding and statistics skills; needs extra libraries (GDAL, rasterio, geopandas)
ENVI	Strong at pre-processing and classifying high-resolution imagery; mature spectral analysis	Paid; focused on image processing rather than prediction modeling — needs to be combined with other software

ADDED VALUE

How the Prediction Model Benefits City Planning

Anticipatory Planning	Spatial policy is set before uncontrolled growth happens
Better-Targeted Infrastructure	Road, water, and energy investment is directed to priority growth areas
Protecting Vulnerable Areas	Early detection of potential farmland and protected-area conversion
Tracking SDG 11 Progress	Forward-looking data supports regular reporting on indicator 11.3.1

CASE STUDY — GREATER TANGERANG

Profile of the Three Greater Tangerang Administrative Areas

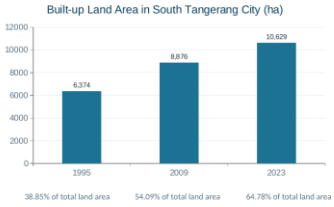
Tangerang Regency
Land Area: 959,61 km²
Districts: 29 districts
Population: ±3.46 million (2024)
Industrial hubs (Balaraja–Cikupa–Legok), coastal areas (north), and new townships

Tangerang City
Land Area: 184.24 km²
Districts: 13 districts
Population: ±1.93 million
Dense population near Soekarno-Hatta Airport; a major hub for industry and services

South Tangerang City
Land Area: 164,85 km²
Districts: 7 districts
Population: ±1.37 million (2021)
Established in 2008; a new hub for housing and business (BSD, Serpong)

CASE STUDY — GREATER TANGERANG

Built-up Area Trends in South Tangerang City



Source: Wahyudi, Somantri & Nandi (2023), Landscape Expansion Index analysis based on multi-date Landsat imagery

Growth Pattern

- **1995–2009: dominated by edge expansion (71.4%) — built-up land spread into new areas around the city**
- **2009–2023: shifted toward infilling (59.6%) — densifying already built-up areas as expansion slowed**
- Growth spread from the east (bordering Jakarta) toward the center and west of the city

CASE STUDY — GREATER TANGERANG

Growth Patterns in Tangerang Regency and Tangerang City

Tangerang Regency

- The largest area, with significant non-built-up land remaining, mainly in the north (coast) and west
- Rapid growth is concentrated in industrial zones and new townships — e.g., Citra Raya (2,760 ha, about 1,000 ha already built up)
- Expansion type: edge expansion and outlying growth along toll road corridors and districts bordering South Tangerang/Tangerang City
- Main risk: uncontrolled farmland conversion

Tangerang City

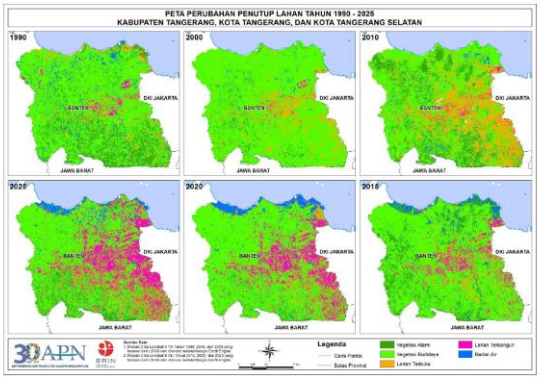
- Long-standing high urbanization — close to Jakarta, Soekarno-Hatta Airport, and older industrial areas
- Built-up growth is now dominated by densification/infilling and conversion to commercial use, rather than new land expansion
- A 2024 Urban Heat Island study found declining vegetation cover and rising surface temperature due to land conversion
- Main risk: environmental pressure and crowding in an area that is nearly saturated

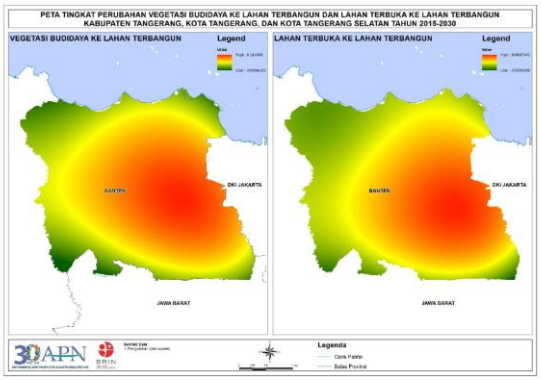
CASE STUDY — GREATER TANGERANG

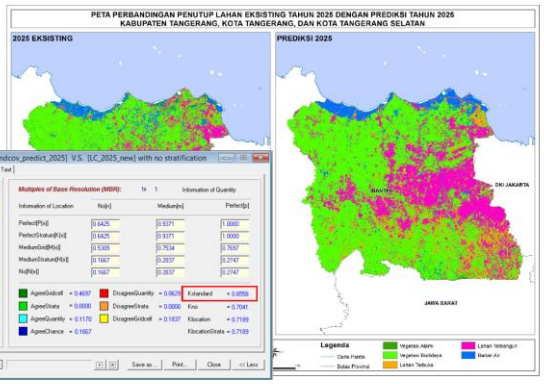
Comparing Growth Patterns and Prediction Model Needs

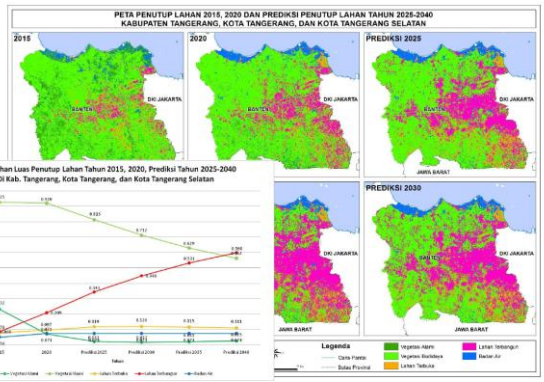
Area	Dominant Expansion Type	Main Driver	Prediction Model Need
Tangerang Regency	Edge expansion and outlying growth	Industrial investment, new townships, toll roads	Predicting sprawl direction to help control farmland conversion
Tangerang City	Infilling / densification	Proximity to the airport and Jakarta, commercial conversion	Predicting density intensification and urban heat impact
South Tangerang City	Edge expansion shifting to infilling	Overflow urbanization from Jakarta, new housing and business districts	Predicting the expansion-to-infill transition to guide RTRW revisions

The three areas are at different growth stages — the prediction model needs to be tailored to each area's characteristics and spatial phase, rather than using one uniform approach.









No	Location	Spatial Pattern (Zone)	Land Cover Class	Class ID
1	Tangerang Regency	Protected Forest Zone	Natural Vegetation	1
2		Livestock Zone	Cultivated Vegetation	2
3		Food Crop Zone	Cultivated Vegetation	2
4		Energy & Mining Zone	Open Land	3
5		Power Generation Zone	Built-up Land	4
6		Industrial Allocation Zone	Built-up Land	4
7		Transportation Zone	Built-up Land	4
8		Rural Settlement Zone	Built-up Land	4
9		Urban Settlement Zone	Built-up Land	4
10		Coastal Buffer Zone	Water Body	5
11		River Buffer Zone	Water Body	5
12		Aquaculture Zone	Water Body	5
13		Lake/Reservoir Buffer Zone	Water Body	5
14		Water Body	Water Body	5

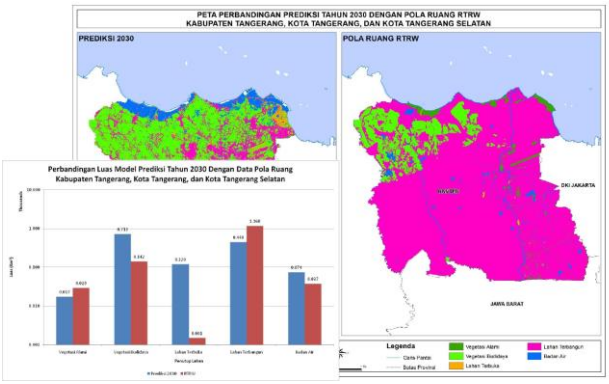
Tangerang Regency 2011-2031

No	Location	Spatial Pattern (Zone)	Land Cover Class	Class ID
1	Tangerang City	Green Open Space Zone	Natural Vegetation	1
2		Energy & Mining Zone	Cultivated Vegetation	2
3		Tourism Zone	Cultivated Vegetation	2
4		Defense & Security Zone	Cultivated Vegetation	2
5		Residential Zone	Built-up Land	4
6		Roads	Built-up Land	4
7		Industrial Zone	Built-up Land	4
8		Rivers/Lakes	Water Body	5
9		Local Protection Zone	Water Body	5

Tangerang City 2012-2032

No	Location	Spatial Pattern (Zone)	Land Cover Class	Class ID
1	South Tangerang City	Green Open Space Zone	Natural Vegetation	1
2		Agricultural Zone	Cultivated Vegetation	2
3		Defense & Security Zone	Open Land	3
4		Tourism Zone	Open Land	3
5		Industrial Allocation Zone	Built-up Land	4
6		Residential Zone	Built-up Land	4
7		Local Protection Zone	Water Body	5
8		Water Body	Water Body	5

South Tangerang City 2015-2025



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CAPACITY BUILDING

Four Pillars of Science-Based City Planning

Human Resources

Training city planners in geospatial analysis, data science, and modeling

Technology and Data Infrastructure

Providing Big Earth Data platforms, computing power, and an integrated database

Institutions and Policy

Regulations for using spatial data in official spatial-plan documents

Multi-Stakeholder Collaboration

Partnerships among government, academia, and research/international institutions

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FRAMEWORK

From Big Earth Data to Achieving SDG 11

Big Earth Data

Satellite imagery and socio-spatial data

Prediction Model

Built-up area modeling

Science-Based Planning

Evidence-based spatial policy

SDG 11 Achievement

Inclusive, safe, and sustainable cities

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REFLECTION

Implementation Challenges and Recommendations

Challenges

- Limited access to consistent, high-resolution data
- Uneven skill levels among staff across regions and agencies
- Integrating model results into formal spatial-planning regulations
- Sustaining long-term funding for data infrastructure

Recommendations

- Build an open, cross-agency integrated data platform
- Expand data-science training programs for regional planners
- Develop technical guidelines for using prediction models in spatial plans (RTRW)
- Strengthen research partnerships with science institutions and international partners

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CONCLUSION

Science and Earth Data as the Foundation for Sustainable Cities

- A built-up area prediction model turns historical data into forward-looking insight for city planners
- Its link to SDG 11 turns spatial data into both a monitoring and a planning tool
- Building capacity in people, technology, institutions, and collaboration is key to sustaining this approach
- Sustainable cities don't happen by chance — they result from planning grounded in science and evidence

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Thank You

THEORY AND HANDS-ON SESSION

Machine Learning for Urban Planning and Spatial Analysis

Mapping land cover with Machine Learning

Dionysius Bryan Sencaki
Hari Prayogi
National Research and Innovation Agency (BRIN)

AGENDA

Concepts — 15 min

Why ML for urban questions, and how a satellite image becomes a machine-learning dataset

Algorithms — 10 min

Random Forest and XGBoost intuition — what they do, when to pick which

Hands-on — 35 min

Train and map a land cover / impervious surface classifier in Python

Noncommercial tiers

Tier	Quota limit	Eligibility	Recommended use
Community Tier	150 EECU-hours (540,000 EECU-seconds)	Available to all verified noncommercial projects. No additional requirements.	Intended for undergraduate students and other users with typical computation needs. This tier supports the majority of noncommercial Earth Engine usage.
Contributor Tier	1,000 EECU-hours (3,600,000 EECU-seconds)	Available to all verified noncommercial projects. An active billing account is required, but you won't be charged for Google Earth Engine noncommercial usage. If you use this project for other Google Cloud services, you may be charged for that usage.	Intended for graduate students, nonprofits, and scientific researchers doing noncommercial work that contributes to science and impact.
Partner Tier	100,000 EECU-hours (360,000,000 EECU-seconds)	Requires a separate application with details about your project and its impact. Approval may take up to several weeks. You can apply for this tier if your project relates to climate mitigation (carbon emissions reduction), adaptation (climate change resilience), or protection (nature and biodiversity protection, management, and restoration).	Intended for Nonprofits/NGOs, university research groups, government research groups, or other organizations with high computation requirements and clear evidence of high-impact sustainability work that influences environment policy and practices.

MOTIVATION

Where ML meets the city

Land cover & impervious surfaces

Map built-up growth, sealed surfaces, and green space from free satellite imagery — the base layer for most urban indicators.

Urban growth & sprawl

Detect change across image time series and model where expansion is likely to happen next.

Hazard susceptibility

Combine terrain, rainfall, and land cover to rank flood or landslide susceptibility for zoning decisions.

Heat & green space

Relate land surface temperature to urban form; find neighborhoods that need greening most.

CORE IDEA

A satellite image is just a table

- Each pixel is one sample (row) — a city becomes millions of training candidates
- Each spectral band or index is a feature (column): Blue, Green, Red, NIR, SWIR, NDVI, NDBI...
- Labels come from reference points you digitize or collect: built-up, vegetation, water, bare land
- Once the image is a table, any tabular classifier works — including RF and XGBoost

This tabular classifier approach has several perks:

- Reproducible, easy integration
- Resources Efficient (at least compared to 2D-based approach within the same ROI coverage)
- Robust performance, comparable to methods that used higher dimension data
- The cloud cover treatment is easier and manageable compared to higher dimensional data.



Raster (pixels)

Red	NIR	NDVI	NDBI	Class
0.09	0.41	0.64	-0.21	Veg
0.21	0.24	0.07	0.18	Built
0.05	0.03	-0.12	-0.30	Water
0.18	0.27	0.20	0.05	Bare

Table (samples × features)

WORKFLOW

Supervised classification, end to end

1 **Imagery** — Sentinel-2 / Landsat composite, cloud-masked

2 **Reference data** — Labeled points per class, well spread

3 **Features** — Bands + indices (NDVI, NDBI, MNDWI) + terrain

4 **Train model** — RF / XGBoost on the sample table

5 **Predict map** — Apply pixel-wise to the full raster

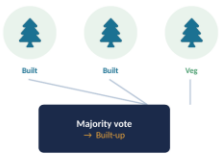
6 **Validate** — Confusion matrix on held-out samples

ALGORITHM 1

Random Forest — wisdom of many trees

- Grows hundreds of decision trees, each on a random bootstrap sample of the training data
- Each split considers only a random subset of features — trees stay diverse, not clones
- Final class = majority vote across all trees
- Key knobs: n_estimators, max_depth, max_features
- RF is renowned for its capability to process data with high dimensionality and interpretable (in the sense of easy feature importance extraction), robust to noise and outlier and require minimal tunning.

Drawbacks : relatively slow dan could be computationally inefficient(deep trees), unable to handle NaN, dan usually has poor generalization.



...typically 100–500 trees, not 3

Visualize

ALGORITHM 2

XGBoost — trees that learn from mistakes

- Builds trees sequentially: each new tree focuses on the errors of the ensemble so far (gradient boosting)
- Regularization built in — strong accuracy with controlled overfitting, which is the biggest upgrade compared to RF -> reduced trees complexity, reduce prediction bias and improved generaliztion
- Often edges out RF on tabular benchmarks, at the cost of more tuning
- Key knobs: n_estimators, learning_rate, max_depth, subsample

Drawbacks : not as resilient as RF when handling noise/outliers

	Random Forest	XGBoost
Training	Parallel trees	Sequential trees
Tuning effort	Low	Moderate
Overfitting risk	Low	Low–medium
Typical accuracy	Strong baseline	Often slightly higher



Visualize

FEATURE ENGINEERING

Give the model eyes for the city

Spectral bands

Blue, Green, Red, NIR, SWIR1, SWIR2 — the raw signal. SWIR is useful for separating built-up from bare soil.

NDVI = (NIR − Red) / (NIR + Red)

Vegetation greenness. High for parks and crops, low for concrete and asphalt.

NDBI = (SWIR − NIR) / (SWIR + NIR)

Built-up index. Highlights impervious surfaces; the workhorse for ISA mapping.

MNDWI = (Green − SWIR) / (Green + SWIR)

Water index. Keeps rivers, ponds, and flooded fields out of your built-up class.

Optional extras: elevation & slope (terrain constraints), texture, and multi-date composites to capture seasonality.

HANDS-ON · SETUP

Our dataset for today

Imagery	Sentinel-2 surface reflectance, cloud-free median composite (10 m)
Study area	Urban–rural gradient around a growing Indonesian city
Features	NDVI, NDBI, MNDWI
Reference	~almost 100 labeled points, stratified across classes
Split	70% train / 30% test (stratified)

Target classes

- Built-up / ISA
- Dense Vegetation
- Sparse Vegetation
- Water

HANDS-ON · SETUP

Tools: a plain Python stack

- Everything runs in python code – for this session, we will use Google Colab
- rasterio reads/writes GeoTIFFs; numpy reshapes rasters into tables
- scikit-learn and xgboost provide the classifiers and metrics
- Same workflow scales up in Google Earth Engine later if needed

ENVIRONMENT

```
pip install numpy rasterio scikit-learn xgboost matplotlib

import numpy as np, rasterio
from sklearn.ensemble import RandomForestClassifier
from sklearn.model_selection import train_test_split
from xgboost import XGBClassifier
```

HANDS-ON · CODE

Step 1–3: raster in, table out

LOAD + SAMPLE

```
# 1. Load the feature stack (bands + indices)
with rasterio.open("features.tif") as src:
    stack = src.read()              # (3, H, W)
    profile = src.profile

# 2. Extract samples at labeled points
X = stack[:, rows, cols].T          # (n_samples, 3)
y = labels                          # class codes 0..4
```

SPLIT

```
# 3. Stratified train / test split
X_tr, X_te, y_tr, y_te = train_test_split(
    X, y,
    test_size=0.3,
    stratify=y,          # keep class balance
    random_state=42)     # reproducible
```

- stratify=y keeps rare classes (often water) present in both splits
- Fix random_state so everyone gets identical numbers
- Sanity-check shapes and class counts before training anything

HANDS-ON · CODE

Step 4–5: train and map

TRAIN

```
# 4a. Random Forest baseline
rf = RandomForestClassifier(
    n_estimators=300, max_depth=None,
    n_jobs=-1, random_state=42)
rf.fit(X_tr, y_tr)

# 4b. XGBoost challenger
xgb = XGBClassifier(
    n_estimators=300, learning_rate=0.05,
    max_depth=3, subsample=0.8,
    random_state=42)
xgb.fit(X_tr, y_tr)
```

PREDICT + EXPORT

```
# 5. Predict every pixel -> map

rf_pred_valid = rf.predict(X_infer).astype("uint8")

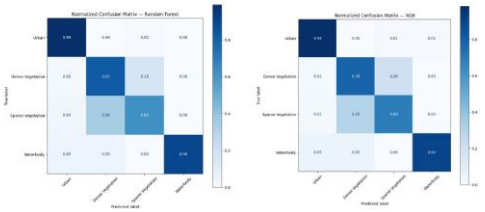
# Work on XGB
xgb_pred_valid_0k = xgb.predict(X_infer)
xgb_pred_valid = np.array([inv_label_map[int(v)] for v in
xgb_pred_valid_0k], dtype="uint8")

def reconstruct(pred_valid, valid_mask, H, W,nodata_out):
          out = np.full(valid_mask.shape[0], nodata_out,
dtype="uint8")
          out[valid_mask] = pred_valid
          return out.reshape(H, W)
rf_map = reconstruct(rf_pred_valid, valid_mask, H, W,
NODATA_OUT)
xgb_map = reconstruct(xgb_pred_valid, valid_mask, H, W,
NODATA_OUT)
```

HANDS-ON · VALIDATION

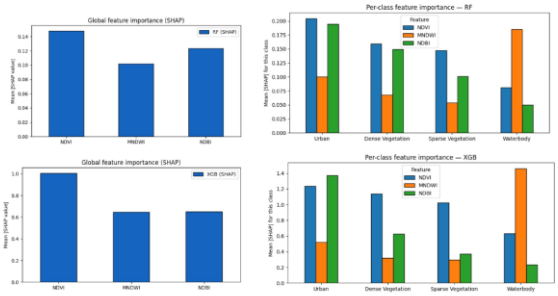
Did it actually work?

- Evaluate only on the held-out 30% the model never saw
- Confusion matrix shows which classes get mixed up
- Report normalized Overall Accuracy for each class



HANDS-ON · INTERPRETATION

What did the model look at?



REALITY CHECK

Four pitfalls that inflate your accuracy

Spatial autocorrelation
Neighboring pixels are near-duplicates. Random splits leak information — prefer spatially blocked splits for honest numbers.

Class imbalance
90% accuracy is easy when 90% of pixels are from dominating class. Stratify samples and read per-class F1, not just OA.

Clouds & shadows
Unmasked clouds become phantom "built-up". QA bands and median composites is needed to be done before training.

Transferability
A model trained on one city can stumble on another season or region — validate before you transfer.

SO WHAT?

From pixels to planning decisions

% ISA
Imperviousness
Sealed-surface share per district drives runoff estimates, drainage design, and flood exposure.

m² / capita
Green space equity
Overlay vegetation with population to find under-served neighborhoods for greening programs.

SDG 11.3.1
Land use efficiency
Land consumption vs. population growth rate — reported straight from multi-year land cover maps.

WRAP-UP

Are you ready to start building land cover classifier?

- A satellite image is a table — pixels are samples, bands and indices are features
- RF is the dependable baseline but XGBoost is the tunable challenger
- Honest validation (held-out data, per-class metric evaluation, spatial awareness) is what makes maps trustworthy

Let's work on that!



SciBUSP Dev Progress

Science-Based Urban Spatial Planning Platform

A comprehensive geospatial platform for smarter, evidence-based urban planning decisions.

Prabu Kresna Putra, S.T., M.T.I
27 Juli 2026

OVERVIEW

What is SciBUSP?

A Django-based geospatial planning platform that combines raster & vector data management, interactive map visualization, and urban analysis modules to support evidence-based spatial planning.

Data Management
Upload, process and register raster and vector spatial layers.

Map Visualization
Three specialized Leaflet-based interactive map viewers.

Urban Analytics
Sprawl, growth, compliance and exposure analysis.

ML Classification
LULC inference with scikit-learn and XGBoost models.

BACKGROUND

Development Objectives

Providing science-based urban spatial planning tools and frameworks that leverage satellite imagery, geospatial data, Big Earth Data, and AI-based analysis. This toolkit helps governments and stakeholders monitor vulnerable areas, control urban expansion, optimize resource allocation, and strengthen urban resilience.

Building the capacity of young scientists and early-career professionals to use earth-observation data in urban planning, then transfer that knowledge to stakeholders in their respective countries. It is tested in selected cities to fit local conditions and needs.

SDG 11

Sustainable Cities and Communities

Supporting evidence-based planning for sustainable cities and communities.

UNDER THE HOOD

Technology Stack

Backend & Processing

- **Django 5** Web framework & request handling
- **PostgreSQL 16** Primary relational database
- **Gunicorn** Production WSGI HTTP server
- **Rasterio** Geospatial raster I/O & reprojection
- **Shapely** Vector geometry operations & overlay
- **scikit-learn & XGBoost** ML model inference
- **TiTiler** On-the-fly COG tile server
- **Docker Compose** Multi-container orchestration

Frontend & Visualization

- **Bootstrap 5** Responsive UI framework
- **Leaflet** Interactive map rendering
- **Chart.js** Data visualization charts
- **WhiteNoise** Static file serving
- **GeoJSON** Vector layer display
- **TiTiler Tiles** Raster layer rendering

PLATFORM MODULES

Key Features

- **Data Management** Manage raster & vector data
- **Data Visualization** Display layers on the map
- **SDG 11 GIS Analysis** Coverage & flood exposure
- **ML / DL Prediction** LULC inference, etc.
- **Social Sensing** Text data & sentiment analysis

Urban-Related Analysis

- Urban Sprawl Comparison
- Urban Sprawl Prediction - Heuristic GIS Model
- Urban Sprawl Prediction - CA Markov Model
- Urban Sprawl Prediction - Deep Learning Model
- Urban Sprawl Regulatory Compliance Analysis

DESIGN

System Architecture

Presentation Layer	HTML Templates + Bootstrap 5 + Leaflet Maps
Request & Orchestration	Django Views (core/views.py): form handling, JSON endpoints, TiTiler proxy
Domain & Persistence	Django Models (core/models.py): SpatialLayer, Job records, Social Media
Processing Layer	Analysis Services (core/services/): Sprawl, Growth, Compliance, LULC, Exposure

Storage: PostgreSQL (metadata & jobs) • Filesystem (rasters, vectors, outputs)

MODULE 1 • DATA MANAGEMENT

The Gateway Module

All analysis tools use the spatial layers created in this module.

Raster Pipeline

1. Upload GeoTIFF (.tif / .tiff)
2. Automatic conversion to Cloud Optimized GeoTIFF
3. Register as a SpatialLayer
4. Ready for visualization & analysis

Vector Pipeline

1. Upload ZIP Shapefile or GeoJSON
2. Extract & normalize to GeoJSON (WGS84)
3. Fill in metadata (theme, area, category)
4. Register as a SpatialLayer

MODULE 1 • DATA MANAGEMENT

Access & Capabilities

Users with access can perform full CRUD operations on both raster and vector data.

Upload & Download
Upload and download spatial data

Edit Metadata
Update theme, area, and category

View Data
Browse all uploaded data

Publish / Unpublish
Control layer availability

Delete Data
Remove unused layers

MODULE 2 • VISUALIZATION

Interactive Layer Controls

Visualize uploaded and published raster & vector data, then interpret it on the map.

Left Panel: Layer Control

- Hide / show layers, search by name
- See currently active layers
- Filter by data type (raster / vector)
- Filter by category (thematic, RBI, spatial planning)
- Filter by study area

Right Panel: Raster Styling

- Inspect the number of pixel classes
- Assign custom colors to each pixel class
- Label each class for readability
- Style configuration saved per layer

MODULE 2 • VISUALIZATION

Vector Styling & Map Identify

Right Panel: Vector Styling

When selecting vector data, users can customize its appearance:

- Stroke & fill color
- Stroke size / weight
- Transparency / opacity

Click-to-Identify Popup

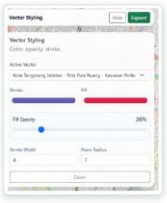
Click on the map to open a popup with detailed information about the feature at that location, so data interpretation can be done directly on the map.

MODULE 2 • VISUALIZATION

Layer & Raster Panels in Action



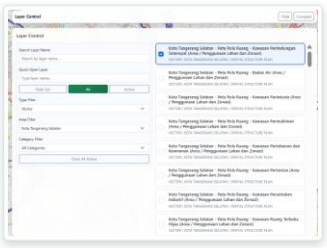
Right raster-styling panel



Right vector-styling panel

MODULE 2 • VISUALIZATION

Interactive Map Viewer



Left layer-control panel

MODULE 2 • VISUALIZATION

Three Specialized Viewers

Data Visualization

- Explore all published raster & vector layers
- Filter layers by metadata attributes
- Rendering COG tile via TiTiler
- Overlay vector GeoJSON on the map

Raster Visualization

- Inspect unique pixel classes (band 1)
- Assign class names & custom colors
- Style configuration saved per layer
- Pixel distribution chart (Chart.js)

RTRW Viewer

- Layers grouped by RTRW theme
- Land use & zoning map view
- Themes: admin, transportation, disaster, utilities
- Grouped thematic layer control

MODULE 3 • SOCIAL MEDIA ANALYTICS

Text Data Upload & Exploration

Data Upload & Parsing

Upload social media data as CSV. The system validates rows, logs errors, and stores parsed records for exploration.

Fields
username, tweet, district, category, date, sentiment

Data Exploration

Browse records in a table interface. Filter by category, location, sentiment, and date to find qualitative insights.

Purpose
Sentiment-based context for planning

MODULE 3 • SOCIAL MEDIA ANALYTICS

Qualitative Signals for SDG 11

Users can view and analyze SDG 11-related data from text across the internet, such as social media and online media.

1. Upload your CSV data
2. Visualized in tabular form
3. Categorized by label class
4. Visualized on the map when coordinates are available

Social Sensing

Adds qualitative context from citizens to complement geospatial analysis in urban decision-making.

MODULE 4 • SDG 11 • SUSTAINABLE CITIES

Vector-Based Analytics

A guided workflow aligned with Sustainable Development Goal 11.

Public Facility Service Coverage

- Select facility, target, road & admin layers
- Service radius parameters are adjustable
- Road-based or proximity-based coverage
- Output: GeoJSON, metrics, CSV export

Flood Exposure Analysis

- Overlay hazard polygons with settlements
- Multi-hazard: flood, erosion, nuclear, all
- Adjustable hazard buffer (Shapely)
- Output: exposure statistics, GeoJSON, CSV

ROADMAP

Critical Infrastructure Vulnerability

Frontend Ready • Backend Analysis Not Yet Implemented

Planned Functionality

Assesses how far infrastructure networks are exposed or vulnerable to hazard layers, using vector overlay analysis similar to the flood exposure module.

- Exposed infrastructure map
- Vulnerable asset statistics per admin region
- List of priority segments for intervention

Inputs

- Infrastructure layer
- Hazard layer
- Admin layer

MODULE 5 • URBAN ANALYTICS

Urban Sprawl Monitor

Detects change between two time periods (T1 and T2) to identify stable urban areas, new growth, and urban loss.

Workflow

1. Select rasters T1 and T2
2. Inspect raster compatibility
3. Define class labels, select the urban class
4. Clipping boundary (optional)
5. Run the change analysis

Outputs

- Result rasters: GeoTIFF & COG
- Summary of urban change metrics
- Complete class transition matrix
- Detailed urban gain & loss table
- Class comparison bar chart

URBAN ANALYTICS • HEURISTIC GIS MODEL

Urban Growth Scenario

Projects future urban expansion using a three-raster sequence, suitability scoring, and scenario rules.

BAU — Business as Usual
Continues historical growth trends without policy intervention.

Compact — Compact Growth
Prioritizes infill and densification near existing urban cores.

Controlled — Controlled Expansion
Enforces constraint boundaries, protected zones, and regulation limits.

Suitability factors: Urban Proximity · Road Access · Center Attraction · Constraint Penalty

URBAN GROWTH SCENARIO • CONCEPT

A Decision-Support Model

The Core Question

"If historical urban growth patterns continue to the target year, which non-urban pixels are most suitable to become urban?"

The module combines historical growth from rasters T1, T2, T3; suitability scores; constraint layers; and scenario rules; then allocates the Top-N best pixels as New Projected Urban.

What It Is NOT

- × Machine Learning
- × CA-Markov
- × SLEUTH
- × Deterministic future prediction

Method: MCE + Weighted Linear Combination + distance-decay scoring + constraint masking + Top-N allocation.

URBAN GROWTH SCENARIO • INPUTS

Raster Time Sequence & Setup

1. **T1 Oldest** — `t0_layer`
2. **T2 Middle** — `t1_layer`
3. **T3 Latest** — `t2_layer` • `baseline`

T3 / latest raster is the current-condition baseline used for projection. All three rasters must be different layers.

Compatibility Inspection

Rasters are compatible when they share the **same class count, same class values, and same area**. Classified rasters only — inspect fails above 64 unique pixel values.

Class Identification

Label every class code, then pick one code as the urban class:

```
1=Water  2=Vegetation  3=Urban
4=Agriculture
```

URBAN GROWTH SCENARIO • RULES

Scenario Adjustment Rules

BAU — Business as Usual

1.00 target multiplier

Urban proximity	input
Road access	input
Center attraction	input

No extra scenario restriction. Full growth target retained.

Compact — Compact Growth

0.90 target multiplier

Urban proximity	× 1.25
Road access	× 0.85
Center attraction	× 1.45

Blocks candidates below urban-proximity quantile 0.55.

Controlled — Controlled Expansion

0.80 target multiplier

Urban proximity	× 0.95
Road access	× 0.70
Center attraction	× 1.10

Blocks candidates below suitability threshold 0.35+.

URBAN GROWTH SCENARIO • SCORING

Suitability Score Components

Urban Proximity
Urban-neighbor density in a 5×5 window, normalized to 0–1.

Road Access
KDTree distance to nearest road, capped at P95 and inverted.

Center Attraction
Distance-decay pull toward nearest activity center.

Constraint Nearness
Distance to nearest constraint, driving the penalty term.

Weighted Linear Combination

Weights are normalized after scenario adjustment.

```
base_score = w_u·urban_proximity + w_r·road_access + w_c·center_attraction
```

URBAN GROWTH SCENARIO • ALLOCATION

Constraints, Blocking & Top-N

Constraint Handling

Soft penalty reduces score near constraints:

```
penalty_factor =
  clip(1 - penalty·constraint_nearness, 0, 1)
```

Hard block zeroes score inside constraints:

```
base_score[constraint_mask] = 0
```

Constraint layers may be vector or raster; multiple layers are unioned.

Top-N Allocation

```
blocked = candidate_non_urban AND
  (constraint OR compact OR controlled)
```

```
eligible = candidate_non_urban AND NOT
blocked
```

Eligible pixels are ranked by base_score; the highest k become New Projected Urban:

```
k = min(target_new_pixels,
count(eligible))
```

URBAN GROWTH SCENARIO • OUTPUT

Output Classes & Deliverables

Result Raster — 4 Classes

1. **Stable Non-Urban** — Valid land, not selected
2. **Existing Urban** — Baseline urban from T3
3. **New Projected Urban** — Top-N allocated pixels
4. **Restricted Candidate** — Blocked by constraint / rule

Deliverables

- Result GeoTIFF + Cloud Optimized GeoTIFF
- Supporting suitability raster (score 0.0–1.0)
- KPI: new urban, annual growth, compactness
- Allocation funnel & suitability profile charts
- Zonal statistics per boundary polygon
- CSV export & A/B scenario comparison

URBAN GROWTH SCENARIO • PIPELINE

End-to-End Workflow

1. Validate raster classes & scenario inputs
2. Prepare the analysis grid & read the raster sequence
3. Estimate historical urban growth rate
4. Compute spatial-driver suitability scores
5. Apply constraints & scenario rules
6. Allocate projected urban pixels (Top-N)
7. Write result raster & output COG

A heuristic suitability-allocation model for decision-support scenario planning, not a deterministic prediction of the future.

URBAN GROWTH SCENARIO • NEXT METHOD

CA-Markov Model

The next urban projection approach available in SciBUSP, combining two classic components of land-change modeling.

Markov Chain

Learns transition probabilities between land classes from historical rasters to estimate how much change will occur.

Cellular Automata

Uses spatial neighborhood rules between pixels to determine where that change is most likely to occur.

Method details will be presented in the next session by Mr. Hari Prayogi.

URBAN GROWTH SCENARIO • NEXT METHOD

Deep Learning Model

A deep-learning-based approach to project urban growth directly from historical data patterns.

Data-Driven Learning

The model learns spatial-temporal patterns of land change directly from historical raster sequences, without manually defined rules.

Complex Spatial Patterns

Has the potential to capture non-linear relationships among urban growth drivers that are hard to model with heuristic approaches.

Method details will be presented in the next session by Mr. Bryan Sencaki.

MODULE 5 • URBAN ANALYTICS

Compliance Checker

Evaluates whether observed urban land-use patterns comply with official zoning regulations — bridging planning regulation data with the actual urban footprint for evidence-based monitoring.

Inputs

- Classified urban raster
- Zoning vector layer
- Admin boundary (optional)
- Constraint layer (optional)
- Rule profile & urban class

Outputs

- Compliance result raster & COG
- Compliance statistics
- Summary per administrative region
- CSV export

MODULE 6 • MACHINE LEARNING

LULC Classification

Machine-learning-powered Land Use / Land Cover inference.

01 **Select Source Raster** — Choose existing raster or upload a multi-band GeoTIFF

02 **Load ML Model** — Use a pre-trained .joblib model (scikit-learn / XGBoost)

03 **Configure Parameters** — Set band count, batch size, and class mapping preset

04 **Run Classification** — Batch-process raster windows through the pipeline

05 **Register Output** — Save classified GeoTIFF as a new SpatialLayer

SECURITY

Authentication & Access Model

Guest
Access to home, terms of service, and privacy policy. No tool access.

Registered User
Created inactive by default. After admin approval, gains full access to data & analysis tools.

Superuser
Manages user approvals and system records via the Django admin interface.

AUTHENTICATION FLOW

Register (inactive) › Admin Approval › Login › Session › **Full Tool Access** › Logout

EXECUTION MODEL

How Analysis Works

Synchronous job execution model.

1. **User Submits Form** — Parameters & layer selections sent via HTML form POST
2. **Job Record Created** — Django stores all input parameters and the user
3. **Service Processes Data** — Engine in core/services/ runs the spatial computation
4. **Outputs Written** — Result files (GeoTIFF, COG, GeoJSON, metrics) saved to disk
5. **Job Updated** — Record updated with metrics, status, and output paths
6. **Result Displayed** — Redirect to detail view: maps, charts, and exports

⚠ *All analysis runs synchronously — long-running jobs may hold Gunicorn workers.*

SUMMARY

Platform Module Overview

Module	Type	Status
Data Management	Ingestion	**Active**
Data Visualization	Viewer	**Active**
Raster Visualization	Viewer	**Active**
RTRW Viewer	Viewer	**Active**
Social Media Analytics	Data + Viewer	**Active**
SDG 11 Vector Analytics	Orchestration	**Active**
Public Facility Coverage	Analysis	**Active**
Flood Exposure Vector	Analysis	**Active**
Urban Sprawl Monitor	Analysis	**Active**
Urban Growth Scenario	Analysis	**Active**
Compliance Checker	Analysis	**Active**
LULC Classification	ML Analysis	**Planned**
Infrastructure Vulnerability	Analysis	**Planned**

SUMMARY

Demo

https://s.brin.go.id/l/SciBUSP

Thank You

SciBUSP — Science-Based Urban Spatial Planning

Building smarter cities through data-driven spatial analysis.

Prabu Kresna Putra, S.T., M.T.I
SciBUSP Forum 2026

MANUAL BOOK
SciBUSP: Science-Based Urban Spatial Planning



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NATIONAL RESEARCH AND INNOVATION AGENCY
2026

A. APPLICATION INFORMATION

The application is used to manage, visualise and analyse geospatial data in support of science-based urban spatial planning and of monitoring progress towards Sustainable Development Goal (SDG) 11 – Make cities and human settlements inclusive, safe, resilient and sustainable.

The application builds on a spatial analysis workflow that was previously carried out separately using desktop Geographic Information System (GIS) software and data-processing scripts. SciBUSP brings this workflow together in a single multi-user web platform, developed at the National Research and Innovation Agency (BRIN), that can be used across South-East Asian countries (it currently holds data for Indonesia, Malaysia and Vietnam). The data processed include land-cover imagery and rasters, thematic vector maps from Regional Spatial Plans (Rencana Tata Ruang Wilayah, RTRW) and social media data.

The main features of SciBUSP are:

a. **Spatial data management** – upload of GeoTIFF rasters (automatically converted to Cloud Optimized GeoTIFF/COG) and vectors (zipped Shapefile/GeoJSON, normalised to GeoJSON WGS84), entry of metadata (RTRW theme, administrative area, category) and layer publication.

b. **Visualisation and dashboards** – Data Visualization (interactive raster and vector maps with style settings), RTRW Viewer (thematic maps) and Executive Dashboard (summary and priority-area ranking).

c. **Spatial Planning Analytics and Modeling** – Urban Sprawl Analysis, Growth Scenario Modeling (BAU/Compact/Controlled), Markov Chain (CA-Markov) Projection, Land Use Compliance against the RTRW/zoning, and Temporal LULC Classification.

d. **SDG 11 Tools** – Public Facility Service Coverage, Hazard Exposure (flood/erosion/nuclear) and Critical Infrastructure Vulnerability.

e. **Social Insights** – upload of social media data (CSV), dashboards by sentiment, category and sub-district, and geo-visualisation.

f. **User management and security** – registration subject to administrator approval, three user roles (Viewer, Analyst, Project Admin) and data access restricted by country.

An example of the SciBUSP interface is shown in Figure 1.

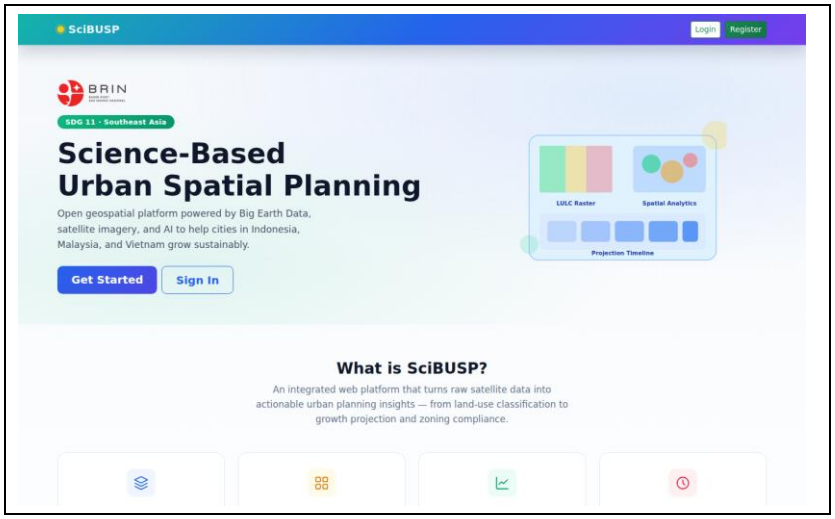


Figure 1. Screenshot of the SciBUSP application (home page)

B. ADVANTAGES OF THE APPLICATION

The advantages of SciBUSP are as follows:

1. **Integrated in a single web platform.** Data management, visualisation, modelling, SDG 11 analysis and decision-support dashboards are all available in one application that is accessed through a web browser, with no need to install desktop GIS software.
2. **Science-based and transparent.** Every analysis module displays its methodology, formulae, parameters and calculation metadata (analysis CRS, pixel area), so that results can be traced and justified.
3. **Accurate area and distance calculation.** Data in geographic coordinates are automatically reprojected to the appropriate UTM zone, so that areas (km²) and distances (metres) are calculated in a metric coordinate system.
4. **Background processing.** Heavy analyses are run by a separate worker through a database-backed queue, so the interface stays responsive, several analysts can work at the same time, and the analysis status (pending/running/completed/failed) is updated automatically.
5. **High-performance raster visualisation.** Rasters are stored as Cloud Optimized GeoTIFFs and served as tiles via TiTiler, and pixel-class names and colours can be saved.
6. **Multi-country and multi-role.** Data are separated by country, and access rights differ for Viewers (decision-makers), Analysts (data managers and analysts) and Project Admins; new accounts become active only after administrator approval.
7. **Ready-to-use outputs.** Results can be downloaded as GeoTIFF, COG, GeoJSON, CSV and PDF reports, and are automatically summarised as a priority-area ranking on the Executive Dashboard.
8. **Easy to install and replicate.** The application is built on open-source software and packaged in Docker containers.

C. NOVELTY OF THE APPLICATION

The novelty of SciBUSP lies in bringing spatial planning analysis, urban growth modelling, SDG 11 indicators and social data together in a single collaborative web platform, specifically:

1. Land-change analysis (urban sprawl), scenario-based urban growth projection (BAU, Compact, Controlled), multi-class Cellular Automata–Markov projection and compliance testing against the RTRW/zoning are run in one workflow that shares a single layer registry.
2. Vector-based SDG 11 indicators (public facility service coverage based on road-network distance, hazard exposure and critical infrastructure vulnerability) and social media signals are combined into a cross-module regional priority score on the Executive Dashboard.
3. Zoning compliance rules (compliant/conditional/non-compliant/ignored) can be configured by the user, supported by automatic inspection of zoning attributes and keyword-based rule suggestions.
4. A multi-country ASEAN architecture with data isolated by country, including authorisation of access to raster tiles.

By comparison, desktop GIS software such as QGIS and ArcGIS Pro offers a comprehensive set of spatial analysis tools, but requires installation, a licence (ArcGIS) and GIS expertise, and provides no multi-user decision dashboard. The CA-Markov models in TerrSet (IDRISI) and the MOLUSCE plugin (QGIS) run on the desktop, separately from spatial plan compliance analysis and SDG 11 indicators. Data-sharing platforms such as GeoNode focus on data cataloguing and publication and have no planning-model modules, while Google Earth Engine requires script programming. SciBUSP combines these capabilities in a single web application that both analysts and decision-makers can use directly.

D. APPLICATION REQUIREMENTS

Programming language	Python 3.12 (main language: backend, spatial analysis and worker); HTML5, CSS3 and JavaScript (ES6) for the interface; SQL (PostgreSQL) via the Django ORM.
Minimum computer requirements	Server: 64-bit processor with at least 2 cores, at least 8 GB of RAM and at least 50 GB of storage (depending on the volume of raster data), running Linux (tested on Ubuntu 24.04 LTS) with a web server. Client: a computer with a modern web browser (latest version of Google Chrome, Mozilla Firefox or Microsoft Edge) and a network connection.
Dependencies on other software	Runs on Docker Engine and Docker Compose; TiTiler 2.0 (COG tile service); GDAL 3.9 via Rasterio 1.4.3; Shapely 2.0.6; pyshp 2.3.1; NumPy 2.4 and SciPy 1.17; scikit-learn 1.5.2; XGBoost 2.1.4; joblib 1.4.2; NetworkX 3.4.2; ReportLab 4.2.5; OpenStreetMap base maps and the Nominatim geocoding service.

Server type *)	Gunicorn 22.0 (WSGI, gthread workers) inside a Docker container; analysis worker (Django run_worker command); TiTiler for raster tile services; WhiteNoise 6.8 for static files.
Database type *)	PostgreSQL 16 (psycopg 3.2 driver); SQLite can be used for local development.
Other frameworks *)	Django 5.0.9 (backend), Bootstrap 5.3.3, Leaflet 1.9.4 and Chart.js 4.4.

E. APPLICATION ALGORITHM

The general algorithm of SciBUSP is shown in Figure 2. After the user logs in, the system checks the user's role. Viewers are directed to the visualisation and dashboard pages, which show only their own country's data. Analysts and Project Admins can upload spatial data, which are converted (rasters to COG, vectors to GeoJSON EPSG:4326) and recorded in the SpatialLayer registry. When an analysis is run, the system validates the inputs and creates a job with the status ‘pending’. A background worker then claims the job (SELECT … FOR UPDATE SKIP LOCKED), runs the module algorithm, saves the results and metrics, and sets the status to ‘completed’ or ‘failed’. The results page tracks the status automatically and displays maps, KPIs, charts and export links.

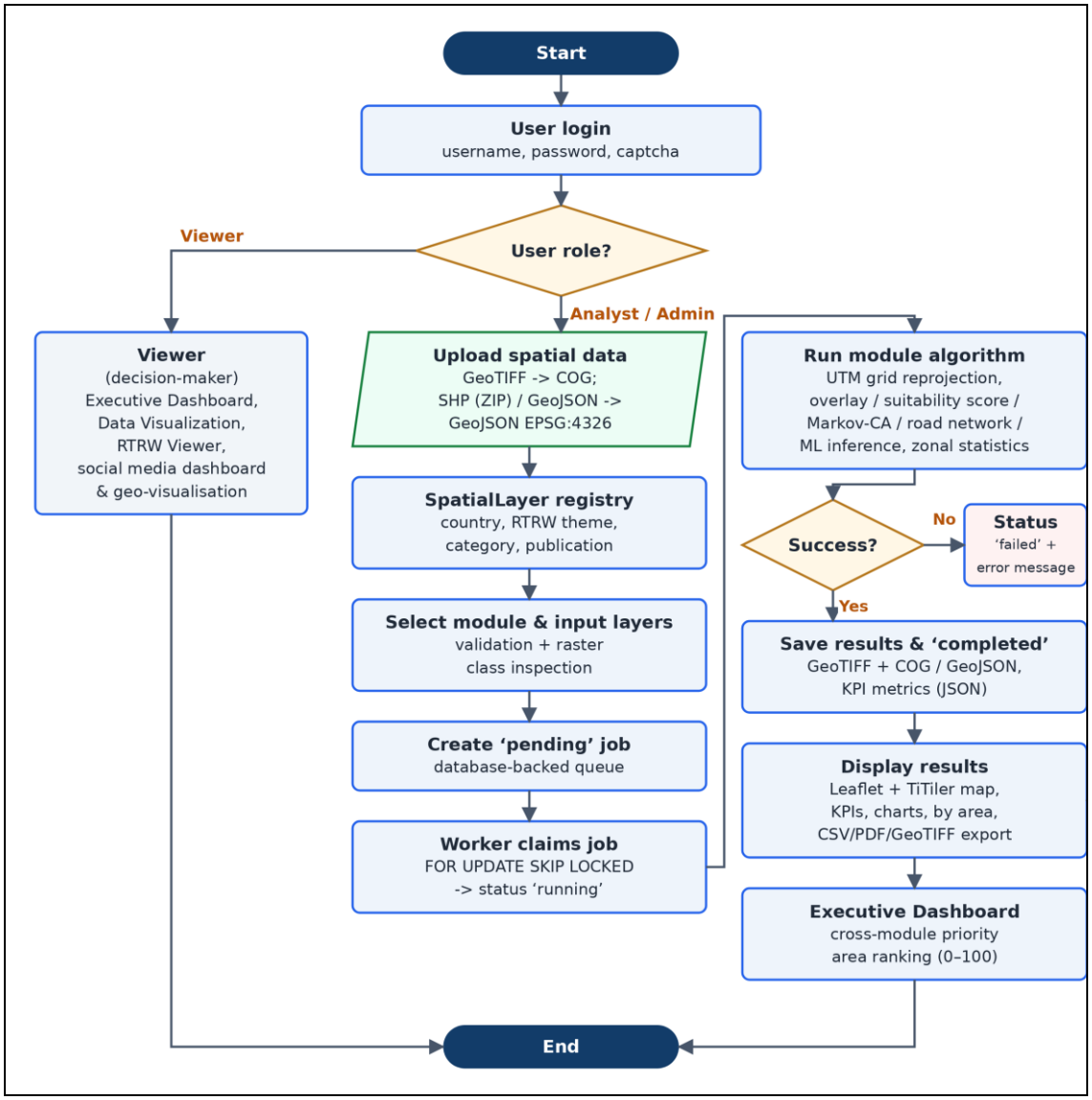


Figure 2. Algorithm of the SciBUSP application

F. HOW TO USE THE APPLICATION

SciBUSP is accessed through a web browser, and the menus shown depend on the user's role. **Viewer** users can access the Executive Dashboard, Data Visualization, RTRW Viewer and the social media visualisation menus. **Analyst** users can access Data Management, social media data upload and all analysis modules. **Project Admin** users can access every menu, plus User Management and the Admin Console. The main menu consists of Executive Dashboard, Data, Social Insights, Modeling, SDG 11 Tools, Spatial Planning Analytics and the account menu. The steps for using the application are described below.

1. Registration and Login

New users select Register and enter a username, first and last names, email address, country, requested role (Viewer or Analyst) and password, then complete the captcha and accept the terms and conditions. The account remains in *Pending Approval* status until a Project Admin

approves it and assigns its role and country. Once approved, the user signs in on the Login page (Figure 3). Profile details and the password can be changed in the Profile menu.

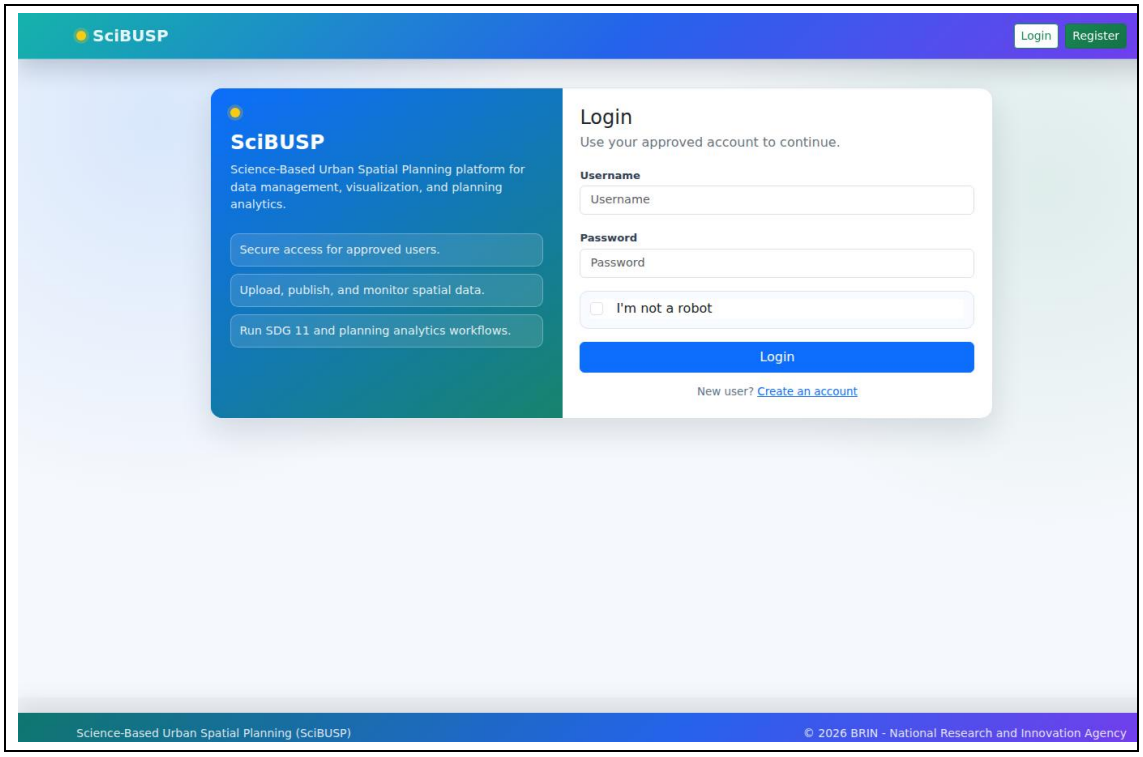


Figure 3. SciBUSP login page

2. Data Management (Analyst/Admin)

The Data › Data Management menu (Figure 4) shows a summary of layer counts and three tabs. The Upload Raster tab is used to upload .tif/.tiff files (up to 200 MB) with a layer name; the system converts them to Cloud Optimized GeoTIFF. The Upload Vector tab accepts one or more zipped Shapefile or GeoJSON files (up to 50 MB per file and 200 MB per upload), with options for layer name, RTRW theme, administrative area and category. The Data Availability tab lists layers with filters for type, area, country, category and publication status. From this table, users can Publish/Unpublish layers, edit metadata, download source or processed files, and delete layers (layer owner or admin only). Only layers with Published status appear in Data Visualization.

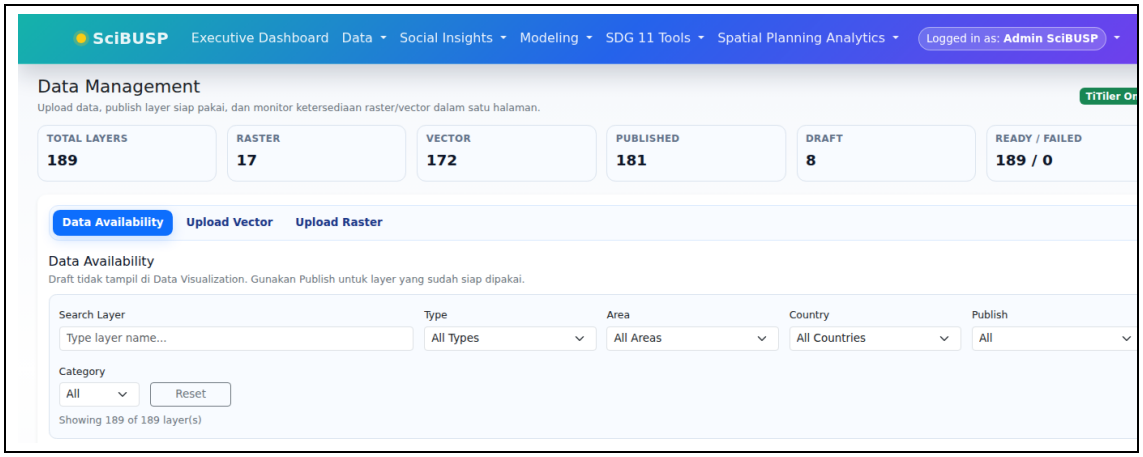


Figure 4. Data Management page

3. Data Visualization

The Data › Data Visualization menu (Figure 5) displays an interactive map. The Layer Control panel is used to search for layers, filter them by type, area and category, and tick the layers to display. The Raster Styling panel is used to inspect raster pixel classes, name and colour each class, choose a colour map and show a pixel distribution chart. The Vector Styling panel sets line and fill colours, opacity, line width and point radius, and zooms to the layer. Click a feature on the map to view its attributes.

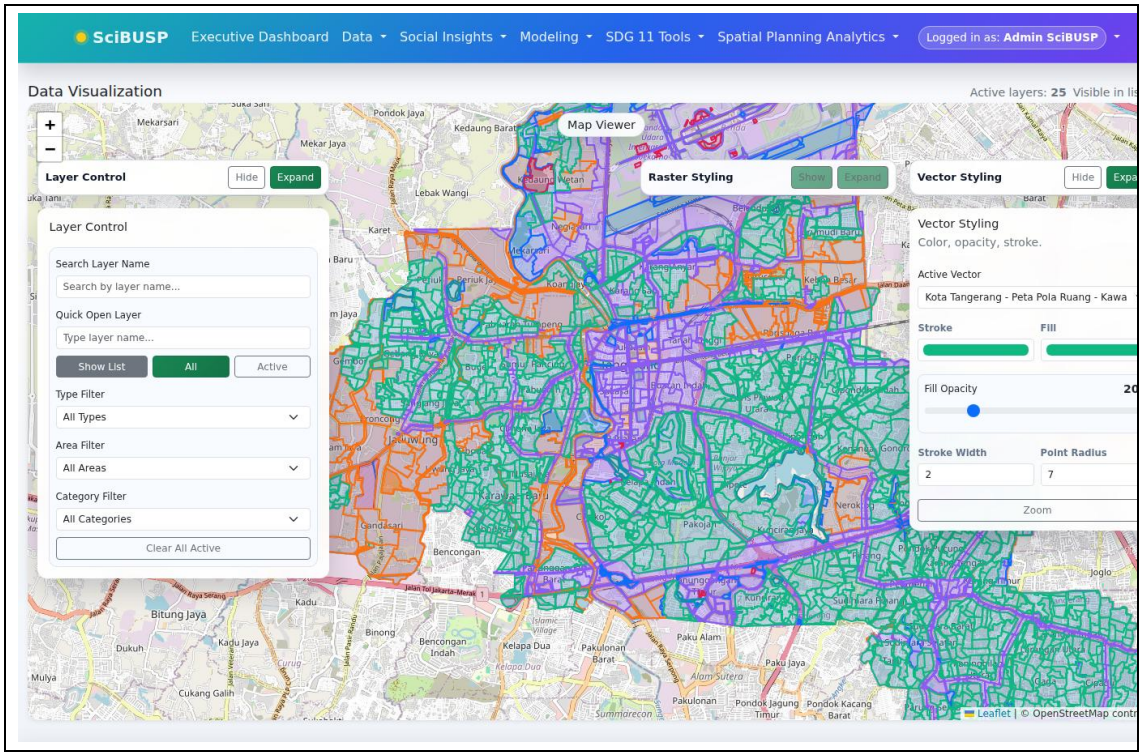


Figure 5. Data Visualization page with a land-use pattern (pola ruang) layer active

4. Regional Spatial Planning (RTRW) Viewer

The Data › RTRW Viewer menu (Figure 6) displays vector layers grouped by RTRW theme (Land Use & Zoning, Administrative Boundary, Transportation Network, Hydrology & Water, and others). The Display Presets buttons (Land Use + Admin, Transport + Hydro + Utilities, Hazard + Topography) switch on groups of layers at once. Click a feature on the map to view its metadata.

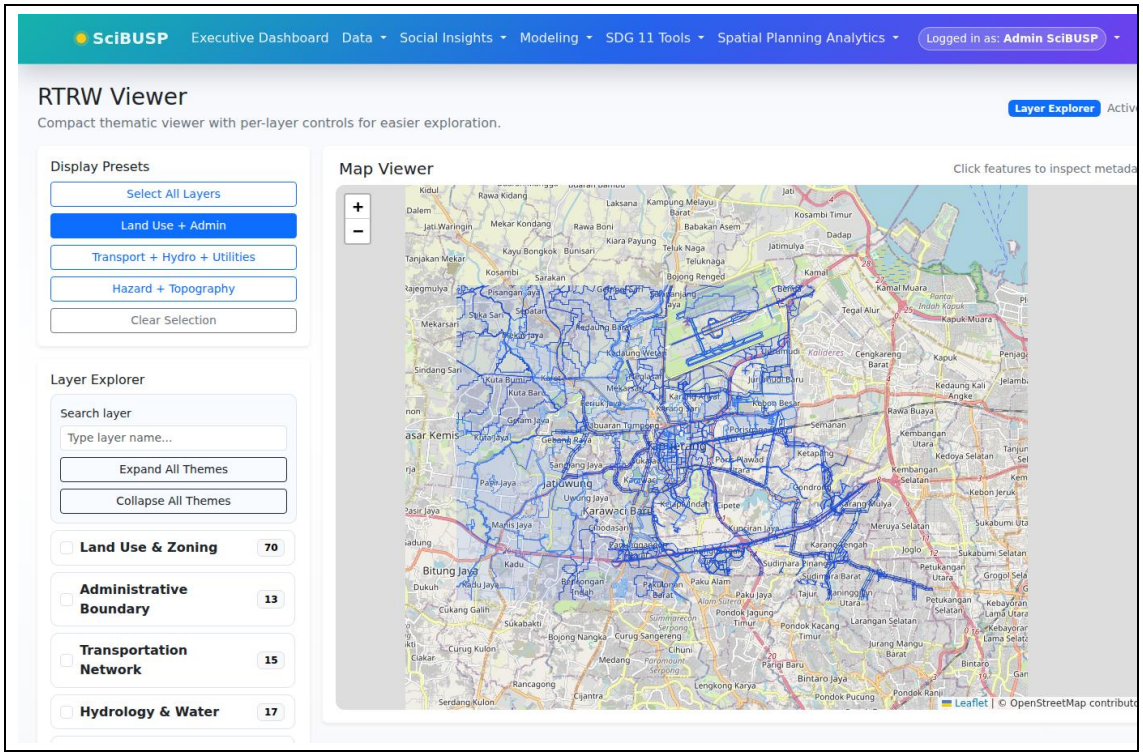


Figure 6. Regional Spatial Planning (RTRW) Viewer

5. Executive Dashboard

The Executive Dashboard menu (Figure 7) displays summary cards (published layers, completed analyses, high-priority areas and social media records), a Priority Area Ranking table that combines the scores of all analysis modules for each area along with its main signals, and a list of Latest Completed Outputs.

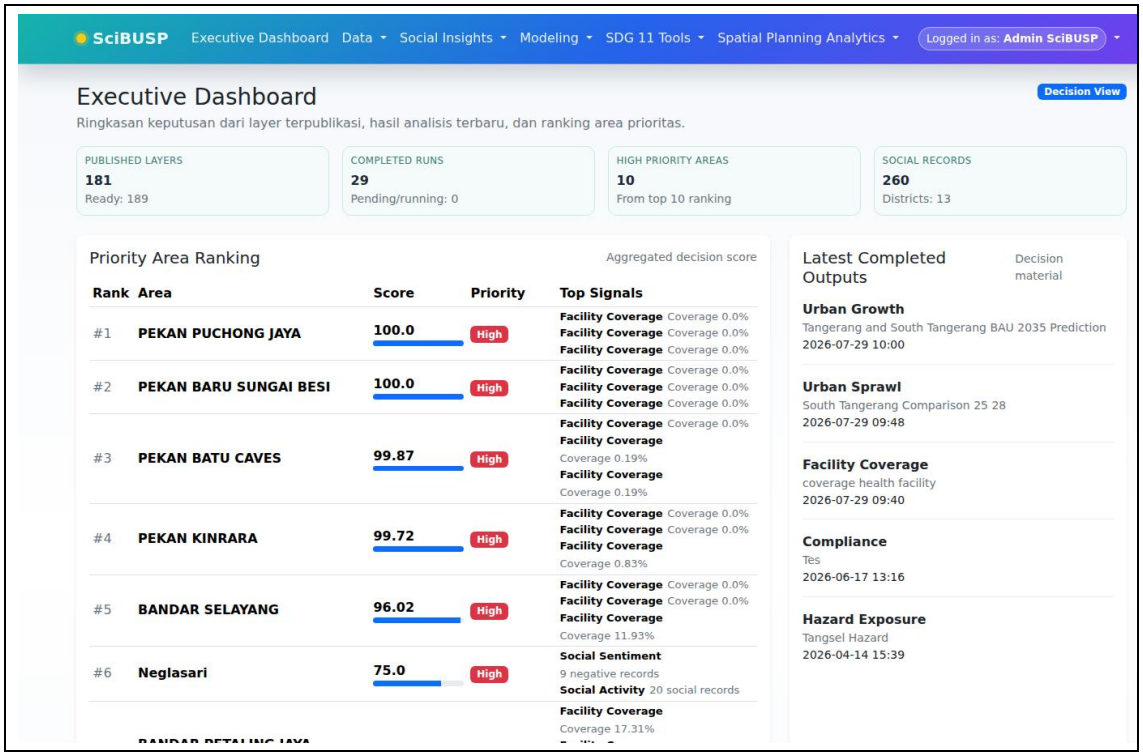


Figure 7. Executive Dashboard page

6. Urban Sprawl Analysis

Select Spatial Planning Analytics › Urban Sprawl Analysis and open the New Analysis tab. Enter an analysis name, select the classified rasters T1 and T2 and, optionally, an area boundary, then click Inspect Raster Compatibility to check that the classes and extents match. Name each pixel class, select the urban class and click Run Analysis. The analysis is queued and the page refreshes automatically. The results (Figure 8) are shown in the Map & Summary tab (change map and new/lost urban area), Change Details (transition matrix), Charts and Technical Info; result files can be downloaded in GeoTIFF and COG formats.

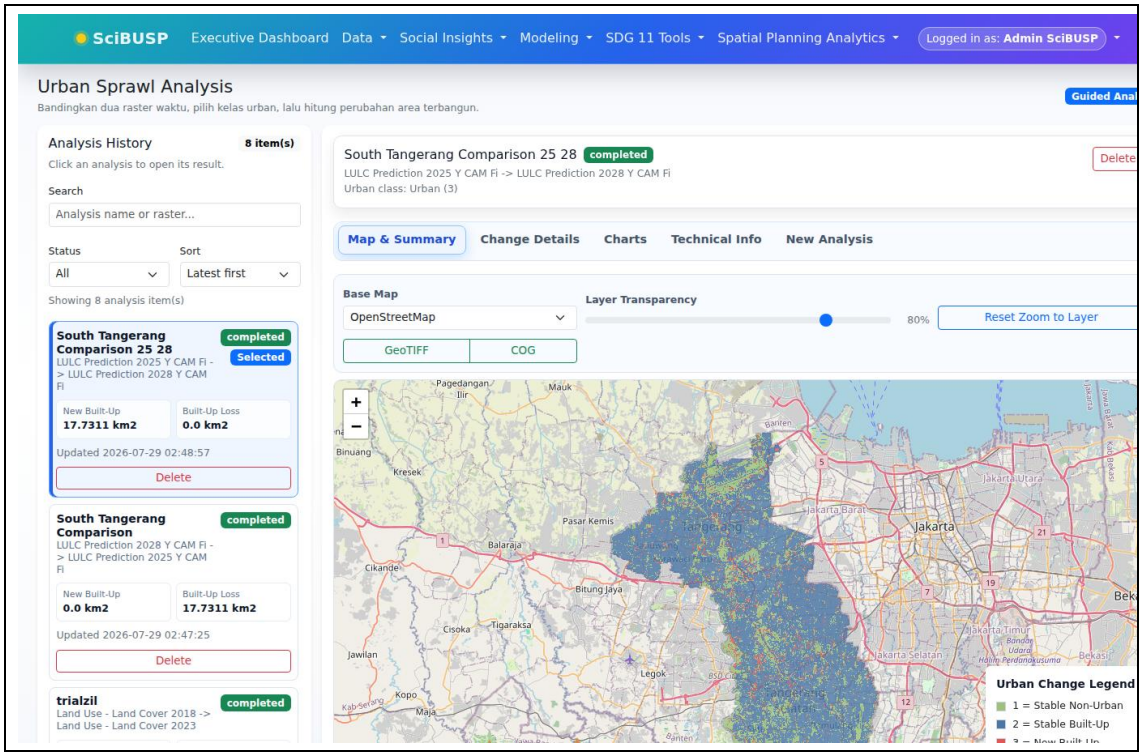


Figure 8. Urban Sprawl Analysis results page

7. Growth Scenario Modeling

In Spatial Planning Analytics › Growth Scenario Modeling, open the New Scenario tab and enter the scenario name, scenario type (BAU, Compact Growth or Controlled Expansion) and target year. Select rasters T1, T2 and T3 with their years, inspect the classes and select the urban class. Add optional spatial drivers (road network, city centres, constraint layer), set the weights and growth target, then run the scenario. The results (Figure 9) are available in the Map & Summary, Analysis Details, Compare Scenarios (comparison of two scenarios), History, Model & Files (download of the result GeoTIFF/COG and suitability map) and Methodology tabs, and can be exported to CSV and a PDF report.

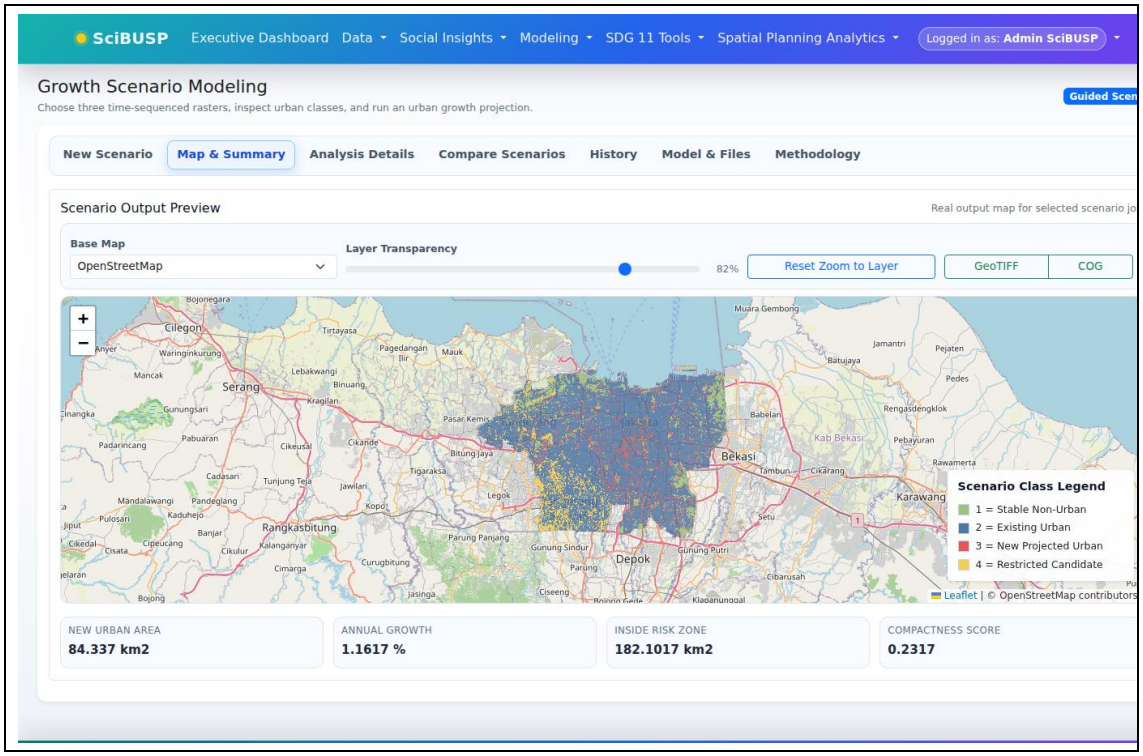


Figure 9. Growth Scenario Modeling results page

8. Markov Chain Projection (CA-Markov)

In Spatial Planning Analytics › Markov Chain Projection, open the New Projection tab, enter the projection name, and select rasters T1 and T2 with their years, the target year and a label for each class. Optional inputs include a validation raster, area boundary, roads, city centres, constraint layer, DEM, water bodies, soil type and population density, as well as the number of CA iterations (5–50) and the neighbourhood size (3×3 or 5×5). Click Run Markov Chain Projection. The results (Figure 10) are shown in the Map & Summary, Transition Matrix, Analysis Details, Validation, History, Model & Files and Methodology tabs, and can be exported to CSV, GeoTIFF and COG.

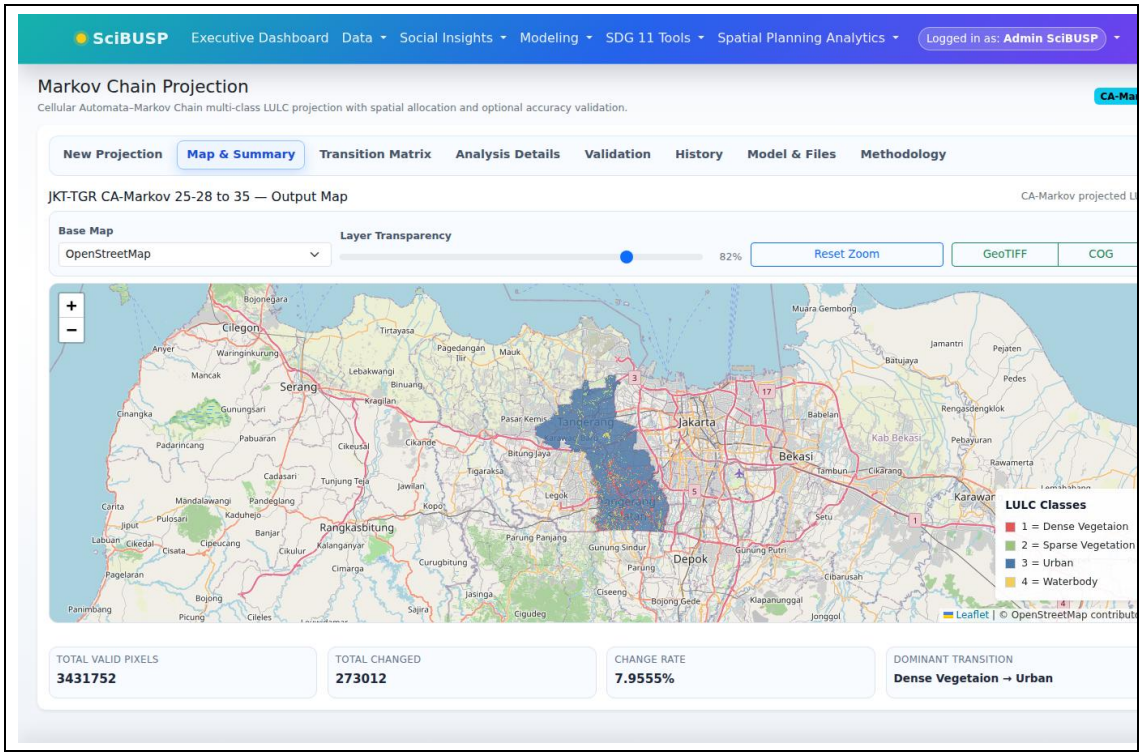


Figure 10. Markov Chain Projection results page

9. Land Use Compliance (RTRW/Zoning)

The Spatial Planning Analytics › Land Use Compliance menu (Figure 11) has four steps: (1) Urban – select the urban raster, click Inspect Classes and specify the urban class value; (2) Zoning – select the zoning/RTRW layer and click Inspect Zoning Fields to choose the category attribute; (3) Rules – map each category to compliant, conditional, non-compliant or ignored, using the Strict, Moderate or Flexible rule profile; (4) Run – run the check. The administrative boundary layer and the no-build layer are optional. The outputs are a compliance map, compliant/conditional/non-compliant areas, the violation rate, breakdowns by category and by area, and a conclusion; they can be exported to CSV, PDF, GeoTIFF and COG.

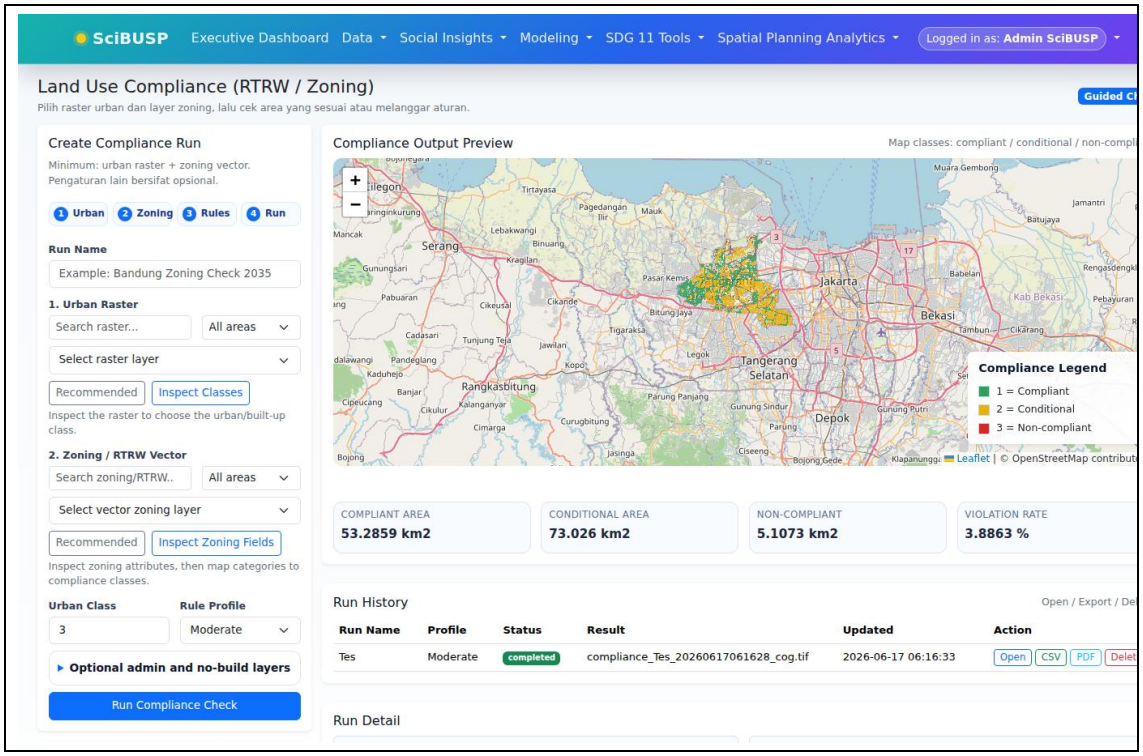


Figure 11. Land Use Compliance page

10. Public Facility Service Coverage

In SDG 11 Tools › Public Facility Service Coverage (Figure 12), enter the analysis name and select the facility layer, the service target layer (polygons), the service radius in metres (minimum 100 m), the road network and the administrative boundary, then click Run Coverage Analysis. The outputs are a map of served/unserved areas and facility locations, KPIs for coverage area and ratio, charts by zone, a list of priority zones and a conclusion; they can be exported to CSV.

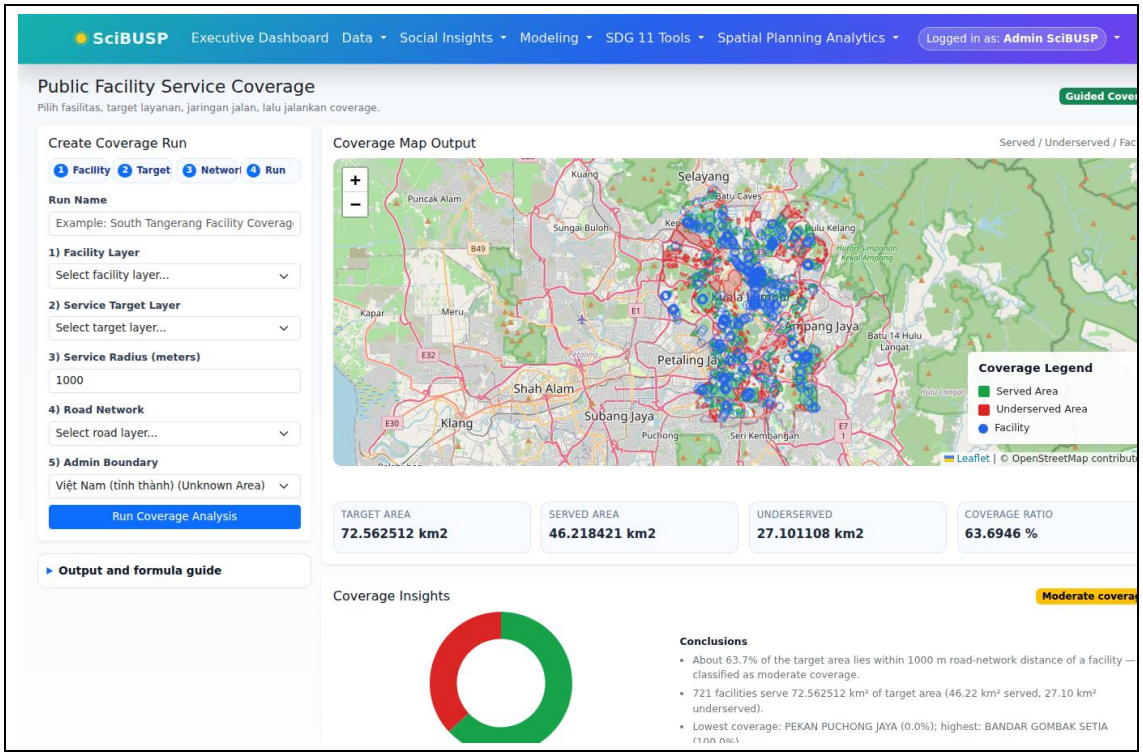


Figure 12. Public Facility Service Coverage page

11. Hazard Exposure

In SDG 11 Tools › Hazard Exposure (Figure 13), select the hazard type (Flood, Erosion, Nuclear or All Hazards), the hazard layer, the buffer distance (metres), the settlement layer, the building layer and the administrative boundary, then click Run Hazard Exposure Analysis. The outputs are a map of hazard zones, exposed/unexposed settlements and exposed buildings, KPIs for exposure and priority level, and statistics by area, which can be exported to CSV.

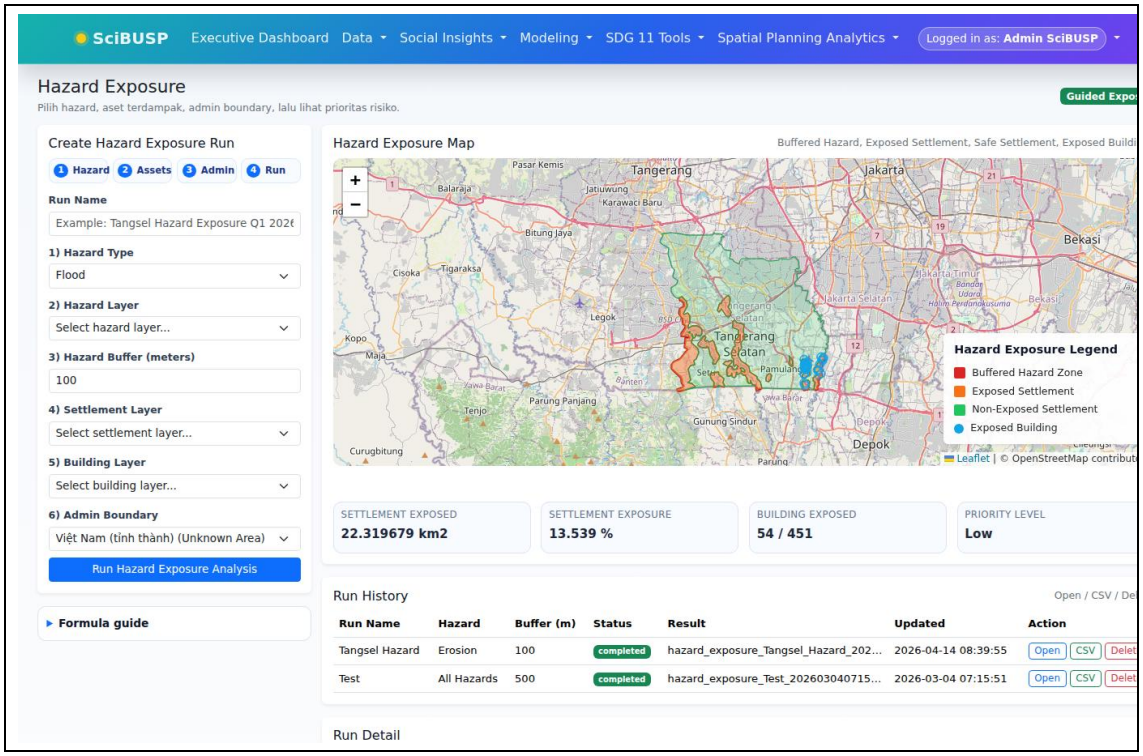


Figure 13. Hazard Exposure page

12. Critical Infrastructure Vulnerability

In SDG 11 Tools › Critical Infrastructure Vulnerability, select the infrastructure layer (road or utility network), the hazard layer, the buffer distance and the administrative boundary, then click Run Vulnerability Analysis. The outputs are a map of exposed and unexposed assets, the number, length and area of exposed assets, the priority level, and statistics by area, which can be exported to CSV.

13. Temporal LULC Classification

The Modeling › Temporal LULC Classification menu provides an interface for temporal land-cover classification (a 52-week time series with 5 feature channels, using a CNN1D model in .keras format). This interface is still under development; the LULC classification inference engine based on .joblib models is already available in the backend.

14. User Management and Logout

Project Admins open account menu › User Management to approve new users, change users' roles and countries, or deactivate accounts. The Admin Console menu provides system-level data monitoring. To leave the application, select account menu › Logout.