Eco. Env. & Cons. 28 (January Suppl. Issue) : 2022; pp. (S529-S534)
Copyright@ EM International
ISSN 0971–765X

http://doi.org/10.53550/EEC.2022.v28i01s.071

Mapping and Estimation of Water Spread Area in Manamelkudi block of Pudukkottai District using Sentinel-1A Data

D. Pandiya Kumar[1], Balaji Kannan[2*], S. Panneerselvam[3], R. Kumaraperumal[4], S. Pazhanivelan[5], K.P. Ragunath[6], N.S. Sudarmanian[7] and M. Venkatesan[8]

[1,4,5,7,8] Department of Remote Sensing and GIS, Tamil Nadu Agricultural University, Coimbatore, T.N., India
[2]Department of Soil Water Conservation Engineering TNAU, Coimbatore, T.N., India
[3]Water Technology Centre, TNAU, Coimbatore, T.N., India
[6]Agricultural Research Station, Bhavanisagar, T.N.,India

(Received 20 August, 2021; Accepted 28 September, 2021)

ABSTRACT

A research study was conducted for mapping and estimation of water spread area using Sentinel-1A satellite data in Manamelkudi block of Pudukkottai district. The most important aspect of water resource planning and management is mapping and regular monitoring of surface water bodies. Remote sensing has become most widely used method for measuring and monitoring of waterbody dynamics due its temporal and spatial availability. European Space Agency's Sentinel-1A data provides high quality SAR data which is used widely used for its ability to penetrate through clouds and illumination independence. The acquired satellite data is processed using SNAP Software. The Water spread area was derived from the processed data using Thresholding approach. The back-scattering values generated through pre-processing in decibel ranges from -7.072 to -29.39 for August 2020 (Pre-Monsoon), -6.189 to -26.634 for December 2020 (Post-Monsoon) and -7.582 to -30.387 for April 2021(Summer). The water spread area in selected 15 Tanks were 52.461 ha, 386.74 ha and 299.41 ha on 17th August 2020, 15th December 2020 and 14th April 2021 respectively.

Key words : *Remote sensing, Sentinel-1A SAR, Thresholding, SNAP software, Water spread mapping.*

Introduction

Water is the main constituent of earth's atmosphere which is vital for foundation of life and essential for most of living organisms. Water covers about 70% of earth's atmosphere in the forms of rivers, ponds, seas, oceans, etc., Surface waterbodies like rivers, ponds, lakes, channels, reservoirs and dams play an important role in socioeconomic development and environmental balance, and irreplaceable natural resources for humans' life and development which includes agricultural, industrial, household, recreational and environmental activities (Song *et al.*, 2016; Pekel *et al.*, 2016). Water is a critical input for agricultural production and plays an important role in food security. Management of water resources involves building of dams or reservoirs around rivers for constructing storages and regulating flows.

([1]PG Scholar, [2] Professor (SWCE), [3] Director [4] Assistant Professor (SS&AC), [5] Professor and Head, [6] Assistant Professor (SS &AC), [7]Research Associate, [8]Senior Research Fellow)
***Corresponding author's email:** pandiydpk000@gmail.com

The most important aspect of water resource planning and management is mapping and regular monitoring of water bodies at river basins/sub basins, lakes, ponds, etc., (Yun *et al.,* 2016).

The conventional methods of calculating water spread usually involves in field survey, which is costly, time-consuming method, require considerable man power and sophisticated instruments. To overcome this problem satellite data is used. In the past decades, numerous satellite sensors capable of monitoring waterbody dynamics were launched. Remote sensing has become most widely used method measuring and monitoring of waterbody dynamics for its timing and accuracy (Dumitru *et al.,* 2015 and Garcia-Pintado *et al.,* 2015). Both Optical and Microwave sensors are used for surface water studies. Optical remote sensing can also be used in monitoring of changes in water surface areas due to its availability. Even though, Optical satellite sensors are affected by cloud cover and cannot provide data during night time which cannot be effective.

Satellite-based SAR (Synthetic Aperture Radar) data is widely used in surface water studies because of its all-weather (Chen *et al.,* 2020), day-and-night sensing capabilities and the ability to detect inundated areas covered by vegetation. Sentinel-1A SAR Ground Range Detected (GRD) in VV polarization is commonly used for its high resolution (10m) and greater accuracy in surface water monitoring (Èotar *et al.,* 2016 and Pham *et al.,* 2017).

Several methods have been proven effective for in monitoring of waterbody and mapping, including thresholding (McFeeters *et al.,* 1996), supervised / unsupervised classification (Lu *et al.,*2007), Decision tree method (*Chen et al.,* 2015), Image segmentation (Jiang *et al.,* 2014), Fuzzy classification (Martinis *et al.,* 2015) and deep learning (Bonafilia *et al.,* 2020). Thresholding techniques on SAR images for surface water mapping are simple and extensively used method since it has greater efficiency, computationally less time-consuming and effectiveness (Gstaiger *et al.,* 2012;) Kuenzer *et al.,* 2013).

Materials and Methods

Study area

South Vellar sub-basin is one of main tributary of Agniyar River Basin with total area of 2010 sq.km. It is bounde by Agniar and Ambuliyar sub basin in the North, Bay of Bengal in East, Velamalai hills and Cauvery basin in West and Pambar basin in South. The sub-basin covers about an area of 2034 km^2 mostly in the districts of Tiruchirappalli and Pudukkottai. It flows for a distance of 137 kilometres from its origin and drains into Bay of Bengal near Manamelkudi taluk of Pudukkottai district. Manamelkudi blocks of Pudukkottai District was selected as study area which has a 15 no. of water storage tanks (Table .1) with total tank area of 1918.635 hectares. The study area map is shown in Fig. .1

Satellite data

In this research Sentinel-1A SAR C-Band (5.405GHz) GRD was used collected from ESA (European Space Agency)'s Sentinel Scientific Data Hub (https://scihub.copernicus.eu/) in Interferometric Wide Swath (IW) Mode. It has dual polarization capacity (HH+HV & VV+VH) with a spatial resolution of 5m*20m, swath of 250 Km and temporal resolution of 6- 12 days. Previous research findings show that VV polarized data provides significantly greater accuracy than VH polarized data in analysing surface water Clement *et al.,* 2017). Three datasets with interval of 4 months viz. August 2020, December 2020 and April 2021 were taken. The Sentinel 1A SAR data was downloaded from Copernicus Open Access Hub (Fig. 2.). The downloaded image optimized through series of processing techniques (Fig..3).

Table 1. List of Water storage tanks

Tank Name	Total Area (In ha)
Namargur Eri	62.932
Thinnayakudi Eri	62.793
Athambur And Vinaitheeratha Eri	142.867
Thalaikottai Eri	43.259
Edayathimangalam Eri	195.462
Ollanur Eri	105.534
Mumbalai Eri	60.68
Keeranur And Vellur Eri	285.11
Thandalai Kanmoi	60.68
Keelakuruchi Kanmoi	41.329
Nelvali_Kanmoi	73.493
Manamelkudi Kanmoi	150.363
Vichur Kanmoi	171.563
Kodikulam Eri	191.157
Manjakudi Kanmoi	271.413
Total Area	1918.635

The pre-processing of Sentinel 1A

The pre-processing was done with SNAP software

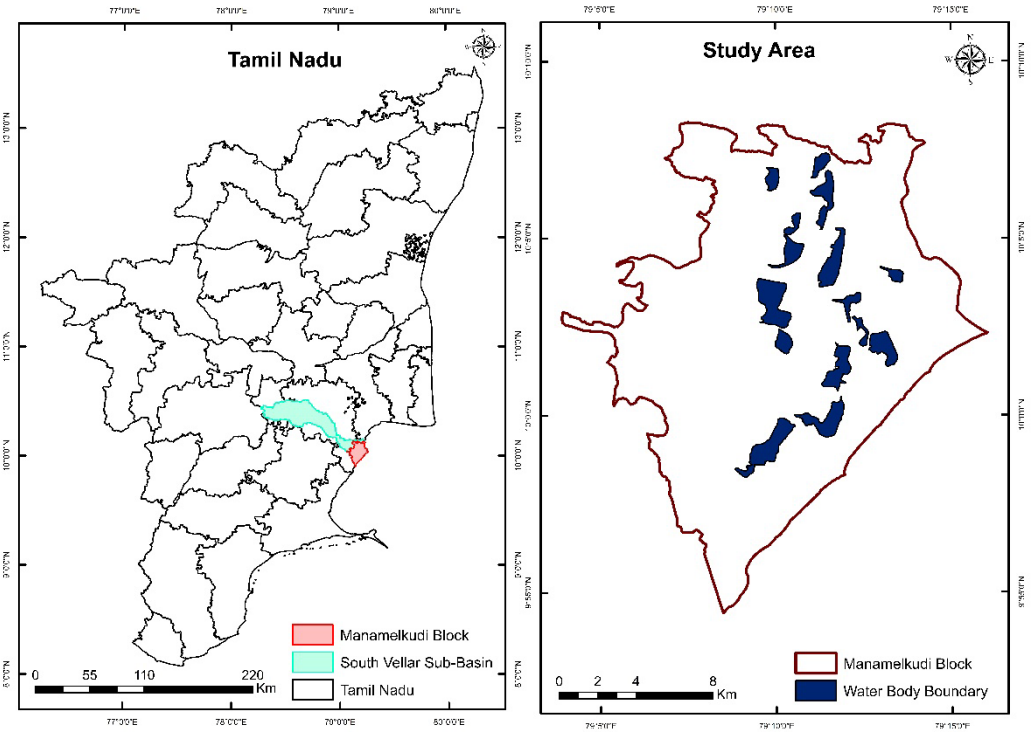


Fig. 1. Location of Water Tanks in Manamelkudi block of Pudukkottai district

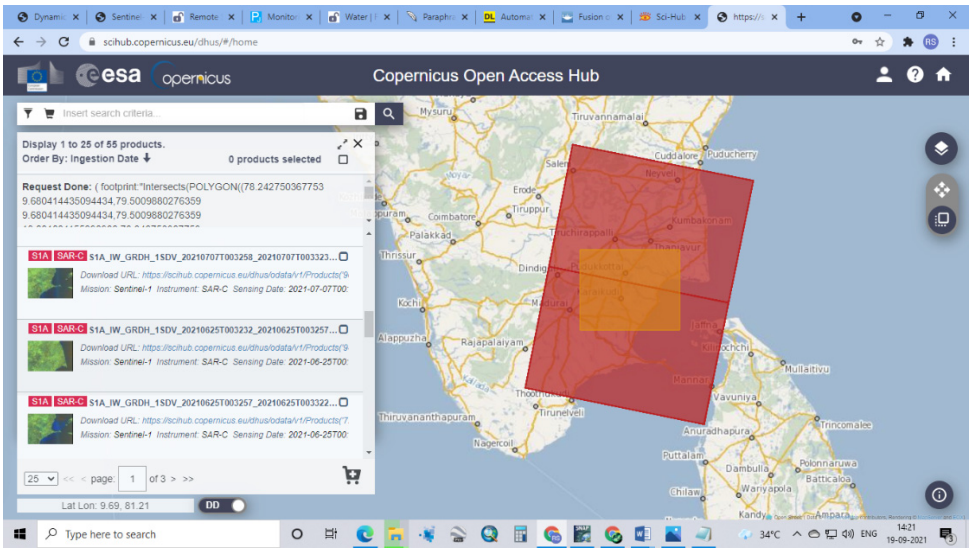


Fig. 2. Overview of Sentinel 1A data acquisition of study area

developed by European space Agency (ESA). The thermal noise in SAR data affects the quality of the image which is removed by S-1 thermal noise removal. Then a precise orbit file was applied, which provides accurate satellite position and velocity information. Radiometric calibration is important process in SAR image for quantitative analysis and è^0 to db. (decibels) were created. Range Doppler Terrain was done to improve geolocation accuracy using SRTM (Shuttle Radar Topography Mission). Then Lee's speckle filter with 7*7 window size (Wu *et al.*, 2015; Amitrano *et al.*, 2014) was applied to remove speckle noises in SAR image and improve image quality.

Thresholding

Various studies applied thresholding value on SAR data in water detection (Tavus *et al.*, 2018; Liang *et al.*, 2019). Thresholding techniques on SAR images extensively used method due of their efficiency and computationally less time-consuming. Here, histogram thresholding method is used for detection of water from non-water area (Schumann *et al.*, 2009; Pulvirenti *et al.*, 2011). The water area maps have been generated using histogram thresholding.

Results and Discussion

Synthetic Aperture Radar satellite data were downloaded in August 2020, December 2020 and April 2021.The download data were pre-processed using SNAP software. The back-scattering values generated through pre-processing in decibel ranges from 5.072 to -29.39 for August 2020, 6.189 to -26.634 for December 2020 and 4.582 to -30.387 for April 2021. Lower (Darker tone) backscattering values corresponds to water pixels while higher (brighter tone) backscattering values corresponds to constructions and settlements. The Intermediate backscatter values corresponds to vegetation, bare land and dry soils.

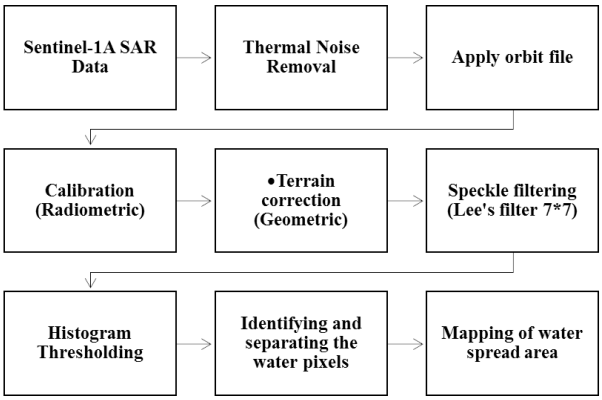
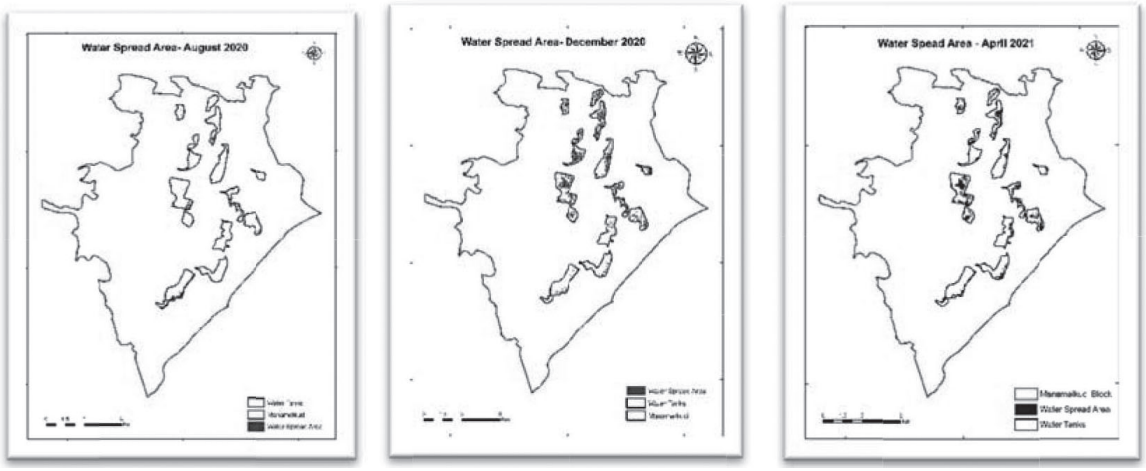


Fig. 3. Methodology for Mapping of Water Spread Area.

Water body area estimation

The thresholding method (histogram thresholding) is commonly used simple and most effective method in generating binary images. The threshold value is derived empirically through manual method (human operator). The db. (decibel) values derived through histogram thresholding were -20 for August 2020, -19 for December 2020 and -21 for April 2021 which used in estimating and mapping of water spread area in tanks. The total water spread area in Water tanks is estimated as 69.57 hectares in August 2020 Fig.3 (a), 386.74 hectares in December 2020 Fig.3.2. (b) and 299.41 hectares in April 2021 Fig..2. (c) is shown in Table.1. The water spread in December is high due to North-East monsoon season and low in August due to post-summer season and it does not receive rainfall in South-West monsoon. The previous studies include Huang *et al.* (2018) and Tavus *et al.* (2018) also used Thresholding approach for mapping of surface water found effective.

Major difference in water spread area observed in Namargur Eri which was completely dry in August 2020, 20 ha water spread in December and 12 ha in April 2021. Manjakudi Kanmoi has highest water spread in August 2020 than December 2020 and



(a) (b) (c)

Fig. 3. Water Spread Area Map - (a) August 2020 (b) December 2020 and (c) April 2021

April 2021. Keeranur And Vellur Eri has water spread in December 2020 and April 2021 than August 2020.

Conclusion

The Thresholding method using Sentinel-1A SAR were used to estimate the water spread area in Manamelkudi block of south velar sub-basin with SNAP software was found to be effective and it confirms that water spread area can be estimated and monitored. The estimated total water spread area in December 2020 is 386.74 hectares, August 2020 is 69.57 hectares and 299.41 hectares in April 2021.

Acknowledgement

The authors thankfully acknowledge the Department of Remote Sensing and GIS, TNAU, Coimbatore for giving guidance for the research work. We also express our gratitude to the Head of the Department, Staff members and colleagues for their valuable comments and positive suggestions given by them during the course of this research work.

References

Twele, André & Cao, Wenxi & Plank, Simon & Martinis, Sandro. 2016. Sentinel-1-based flood mapping: a fully automated processing chain. *International Journal of Remote Sensing*. 37. 2990-3004. 10.1080/01431161.2016.1192304.

Bonafilia, D., Tellman, B., Anderson, T. and Issenberg, E. 2020. Sen1Floods11: a georeferenced dataset to train and test deep learning flood algorithms for Sentinel-1. 2020 IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshops (CVPRW), 835-845. 10.1109/CVPRW50498.2020.00113.

Chen, Y., Qiao, S., Zhang, G., Xu, Y.J., Chen, L. and Wu, L. 2020. Investigating the potential use of Sentinel-1 data for monitoring wetland water level changes in China's Momoge National Nature Reserve. PeerJ 8: e8616. http://doi.org/10.7717/peerj.8616.

Chen, Chien-Ta; Hung, Chia,-Tse ,Lin, Jyh,-Dong and Sung, Po-Hsun 2015. Application of a decision tree method with a spatiotemporal object database for pavement maintenance and management. *Journal of Marine Science and Technology*. 23(3), DOI: 10.6119/JMST-014-0327-5.

Clement, Prabhakar, John, Gerald and Yin, Fah. 2017. Assessing the Increase in Background Oil–Contamination Levels Along Alabama's Beaches Resulting from the Deepwater Horizon Oil Spill. *Oil Spill Science and Technology* (2nd edition pp 851-888). https://doi.org/10.1016/B978-0-12-809413-6.00016-3.

Èotar, K., Oštir, K., and Kokalj, •. 2016: Radar Satellite Imagery and Automatic Detection of Water Bodies. *Geodetski Glasnik,* 50(47): 5-15

Donato Amitrano, Gerardo Di Martino, Antonio Iodice, Daniele Riccio, Giuseppe Ruello, Fabio Ciervo, Maria Nicolina Papa & Youssouf Koussoubé 2014. Effectiveness of high-resolution SAR for water resource management in low-income semi-arid countries. *International Journal of Remote Sensing*. 35:1, 70-88, DOI: 10.1080/01431161.2013.862605

Du, Y.; Zhang, Y., Ling, F., Wang, Q., Li, W., Li, X. Water Bodies' Mapping from Sentinel-2 Imagery with Modified Normalized Difference Water Index at 10-m Spatial Resolution Produced by Sharpening the SWIR Band". *Remote Sensing*. 2016, *8*, 354. https://doi.org/10.3390/rs8040354.

Dumitru, Corneliu & Cui, Shiyong & Faur, Daniela & Datcu, Mihai. 2015. Data Analytics for Rapid Mapping: Case Study of a Flooding Event in Germany and the Tsunami in Japan Using Very High Resolution SAR Images. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing. 8. 114-129. 10.1109/JSTARS.2014.2320777.

García-Pintado, Javier, David C. Mason, Sarah L. Dance, Hannah L. Cloke, Jeff C. Neal, Jim Freer, and Paul D. Bates. 2015. "Satellite-supported flood forecasting in river networks: A real case study." Journal of Hydrology 523:706-724. doi: https://doi.org/10.1016/j.jhydrol.2015.01.084.

Gstaiger, Veronika and Huth, Juliane and Gebhardt, Steffen and Wehrmann, Thilo and Kuenzer, Claudia. 2012. "Multi-sensoral and automated derivation of inundated areas using TerraSAR-X and ENVISAT ASAR data". *International Journal of Remote Sensing* - 33. 7291-7304. 10.1080/01431161.2012.700421.

Huang, W., DeVries, B., Huang, C., Lang, M.W., Jones, J.W., Creed, I.F., Carroll, M.L. *Automated extraction* of surface water extent from Sentinel-1 data. *Remote Sensing. 10*: 797

Jiang, H., Feng, M., Zhu, Y.Q., Lu, N., Huang, J.X., Xiao, T. "An automated method for extracting rivers and lakes from Landsat imagery. *Remote Sensing.* 2014, *6*, 5067–5089.

Liang, Hongnan and Jia, Heming and Zhikai, Xing and Ma, Benedict and Peng, Xiaoxu., 2019. "Modified Grasshopper Algorithm Based Multilevel Thresholding for Color Image Segmentation, *IEEE Access*. PP. 1-1. 10.1109/ACCESS.2019.2891673.

Lu, Dengsheng, 2007. "A Survey of Image Classification Methods and Techniques for Improving Classification Performance". *International Journal of Remote Sensing.* 28. 823 - 870. 10.1080/01431160600746456.

Martinis, Sandro and Kersten, Jens and Twele, André. (2015). A fully automated TerraSAR-X based flood service. *ISPRS Journal of Photogrammetry and Remote Sensing*. 104. 203-212. 10.1016/j.isprsjprs.2014.07.014.

McFeeters, S.K. 1996 The use of the Normalized Difference Water Index (NDWI) in the delineation of open water features". *International Journal of Remote Sensing*.1996, *17*: 1425–1432.

Pekel J-F, Cottam A, Gorelick N:Belward, AS. 2016. "High-resolution mapping of global surface water and its long-term changes*". Nature* 540(7633):418-422

Pham, Binh & Prigent, Catherine and Aires, Filipe. 2017"Surface Water Monitoring within Cambodia and the Vietnamese Mekong Delta over a Year, with Sentinel-1 SAR Observations". *Water*. 9. 10.3390/w9060366.

Pulvirenti, Luca & Pierdicca, Nazzareno & Chini, Marco & Guerriero, Leila. (2011). "An algorithm for operational flood mapping from Synthetic Aperture Radar (SAR) data using fuzzy logic". *Natural Hazards and Earth System Sciences*. 11. 10.5194/nhess-11-529-2011.

Schumann, G., R. Hostache, C. Puech, L. Hoffmann, P. Matgen, F. Pappenberger, and L. Pfister. 2007. "High-Resolution 3-D Flood Information from Radar Imagery for Flood Hazard Management." *IEEE Transactions on Geoscience and Remote Sensing* 45 (6): 1715–1725. doi:10.1109/TGRS.2006.888103.

Sree, Manju and Kumar, L., and Bhatt, C M and Srinivasa Rao, Goru and Veerubhotla, Bhanumurthy, 2012. "Optimization of Threshold Ranges for Rapid Flood Inundation Mapping by Evaluating Backscatter Profiles of High Incidence Angle SAR Images". *International Journal of Disaster Risk Science*. 2012. 113-122. 10.1007/s13753-012-0011-5.

Song J-H, Kang, MS, Song, I, Jun, SM. 2016. "Water balance in irrigation reservoirs considering flood control and irrigation efficiency variation". *Journal of Irrigation and Drainage Engineering* 142(4):04016003

Tavus, Beste & Kocaman, Sultan and Nefeslioðlu, Hakan and Gokceoglu, Candan. (2019). "Flood Mapping Using Sentinel-1 SAR Data: A Case Study of Ordu 8 August 2018 Flood". *International Journal of Environment and Geoinformatics*. 6. 333-337. 10.30897/ijegeo.666212.

Uddin, K., Matin, M.A., Meyer, F.J.2019 Operational flood mapping using multi-temporal Sentinel-1 SAR images: A case study from bangladesh. *Remote Sensimg*. 2019, 11, 1581.

Xu Yuan, Xiao-chun Zhang, Xiu-gui Wang, and Yu Zhang, Flood disaster monitoring based on Sentinel-1 data: A case study of Sihu Basin and Huaibei Plain"' *China,Water Science and Engineering*, 14(2):2021, Pages 87-96, ISSN 1674-2370, https://doi.org/10.1016/j.wse.2021.06.001.

Wu, S., Liu, R., Yommy, A.S. "SAR image despeckling using refined Lee filter". In Proceedings of the 2015 *7th International Conference on Intelligent Human-Machine Systems and Cybernetics (IHMSC)*, Hangzhou, China, 26–27 August 2015.