Received: 18 June 2023 | Revised: 25 July 2023 | Accepted: 16 September 2023 | Published online: 23 October 2023

REVIEW

Green and Low-Carbon Economy
2023, Vol. 00(00) 1–9
DOI: 10.47852/bonviewGLCE32021242
BON VIEW PUBLISHING

Applications of Remote Sensing as Climate Resilience Technique: A Bibliometric Research Trends Analysis

Arpita Ghosh[1,*]

[1]*Indian Institute of Management Sirmaur, India*

Abstract: Regional variances in climate, soil, and topography make agricultural production systems particularly fragile. Animal health is negatively impacted by variations in air temperature, precipitation, frequency, and intensity of extreme weather events. For its assessment and administration, cutting-edge methods like remote sensing (RS), global positioning systems, and geographic information systems (GIS) might be very beneficial. The RS and GIS are essential tools with numerous applications for tackling these problems. The impact of climatic and human-induced changes on the environment is receiving more attention as a result of climate change (CC). Due to CC and human activity, "desertification" describes the degradation of land in arid, semiarid, and dry sub-humid regions. Natural resource sustainability in changing climates can be obtained with the application of RS and GIS. In this review article, the issues toward wildlife were demonstrated and the application of RS was discussed to reduce the impact of CC to save the wildlife and its preservation. Further, the bibliometric analysis was conducted via R-studio Bibliometric tool, which entailed that developed countries (USA, Canada, Germany) are more forward to applying RS tool to mitigate climate risks.

Keywords: remote sensing, climate change, geographic information systems, impact, bibliometric analysis

1. Introduction

Extreme climate change (CC) is the cause of drought or flood, which results in to damage the life and livelihood of the local community. Regional variances in climate, soil, and topography make agricultural production systems particularly fragile [1–5]. Dash et al. [6] revealed CC mostly has negative effects on the occurrence, spread, and outcome of pandemics. The combined changes in air temperature, precipitation, frequency, and severity of extreme weather events have a negative impact on animal health and welfare [7]. Studies of the effects of CC on biodiversity have frequently overlooked the essential importance of plant–animal interactions in ecosystems [8]. By slowing down biomass losses in the basins of the Pacific, Atlantic, and Indian oceans, the CC mitigation strategies may be able to mitigate the effects on marine animal biomass [9]. The major contributors to rising GHG emissions were soil texture, climate zone, and crop type [10]. According to the application of a theoretical model [11], the evolutionary burden imposed by insufficient adaptive responses to continuing CC may already be endangering the survival of species.

The human-induced desertification can be preventable, but desertification caused by CC is unavoidable. For a variety of causes, including landslides, erosion, land planning, and global warming, changes in land use/land cover (LULC) at regional scales are required. On a global and regional scale, changes in LULC (due mostly to human activities) have a negative impact on climatic trends, natural hazard patterns, and social-economic dynamics. Desertification has become a severe economic, social, and environmental issue in India's western region. Nowadays, RS is used to track the desertification process by identifying suitable indicators as proposed by FAO and UNEP. Due to its encroachment on the eastern boundary, the Great Indian Desert, also known as the Thar Desert, has become a challenge for the surrounding regions [12]. Advanced methods like global positioning systems (GPS), geographic information systems (GIS), and remote sensing (RS) can be particularly useful in evaluating and controlling them. In order to address these issues, RS–GIS are essential tools with a wide range of uses for distributing information on a regional scale. When making strategic decisions about food security, import/export, and economic impact, producers, managers, and politicians can substantially benefit from fast and accurate information on crop acreage, growth conditions, and yield estimation. With the aid of RS and GIS, it is feasible to evaluate land use and cover as well as calculate the damage brought on by drought, floods, and other climatic per Figure A1 shows. A larger range of applications is offered by multispectral and hyperspectral imaging-based RS technologies. Chlorophyll pigment absorbs blue and red wavelengths of the electromagnetic spectrum while reflecting the green portion of the spectrum. Although their reflectance qualities in the visible and near-infrared spectrums steadily rise, blue wavelengths are less reflected by soil. Soil reflectance increases in the red region of the spectrum when iron oxides are present. It is crucial to use cutting-edge techniques, such as RS–GIS, geostatistics, and hydrologic

*Corresponding author: Arpita Ghosh, Indian Institute of Management Sirmaur, India. Email: arpita.ghosh@iimsirmaur.ac.in

models, to efficiently monitor and manage water resources and climate risk.

Animal diversity in the forest, on the other hand, is rapidly disappearing. The importance of wildlife in maintaining environmental balance cannot be overstated [13]. Wildlife regulates a variety of natural processes in the environment. Wildlife is important for a variety of reasons, including ecological, economic, investigative, and biological diversity conservation. Our capacity to protect biodiversity, manage invasive species, and conduct research is enhanced by having accurate, detailed, and current knowledge about the whereabouts, mobility, and behavioral patterns of animals [14]. Poaching is a criminal act that focuses on selling animal parts in a foreign market. The basis for the study is a detailed count of the animals in a certain area [15, 16]. The ability to gather data on free-ranging wildlife has historically been constrained by limitations in manual data gathering (such as extrapolating transect counts), but this has significantly improved as a result of RS automation. The most often used RS tools in animal ecology are n-animal sensors. They are typically employed to follow the movements of animals (i.e., GPS data). By taking into account changes in the landscape's structure, the location of the warning signal, and other variables, GIS has looked into the locations of wildlife-vehicle collisions (WVC). Any video-based application that requires object reasoning must do visual tracking since it enables the creation of object connections across frames. Based on an object's present location in the first frame, a visual tracking approach tries to predict the position of any random object of interest in all subsequent frames.

In this review article, the issues toward wildlife preservation were demonstrated. The application of RS–GIS was demonstrated to reduce the impact of CC and to save the wildlife. The bibliometric analysis was performed to understand the research trend in this domain, such as publication rate, most stressed words by scientific community, most influential authors, and influential articles in research community.

2. Critical Discussion

Table 1 shows applications of RS and GIS to mitigate CC and for protection of wildlife from recent literature.

Nowadays, fences and barriers surround the road to avoid WVC. To test their efficiency and effectiveness, a research study is conducted in Freyung-Grafenau, Germany, on a 113-km-long road having both fences and barriers at different points of roads. In this research, a total of 1571 WVCs were examined. It was concluded that fences seem to shift part of the risk at the end of the fences. So, to find the perfect relation between collision and infrastructure, a deep study requires analyzing the road facility by taking photos and gathering the data [18].

Table 1
Applications of remote sensing and GIS to mitigate climate change and for protection of wildlife

Aim	Place of the study	Methods	Findings	References
Analyzing land use/land cover changes in Rize	North-East Turkey	Remote sensing and GIS	The study identified agriculture, bare soil, coniferous, deciduous, pasture, urban, and water as LULC classes	Reis [17]
What effect does roadside infrastructure such as crash barriers and fences have on the occurrence of WVCs in a given area?	Freyung-Grafenau, Germany	WVC statistics and GIS-based model	Crash barriers appear to have a bigger deterrent effect on badgers and foxes. However, street segments without crash barriers have a two-fold higher (2.16) risk of accidents than segments with crash barriers for the area's major deer population	Pagany and Dorner [18]
The model uses the concept of path in graph theory to ensure contiguity and minimizes the sum of distances between selected sites and a central site in individual reserves to promote compactness	–	Graph theory	One potential impact of corridors is to synchronize population dynamics and increase the likelihood of metapopulation extinction	St John et al. [19]
To find the effect of climate and human-induced changes on vegetation	Churu, Rajasthan	Remote sensing; NDVI data	Climate-induced processes account for 64.54% of desertification, whereas human-induced changes account for 35.46%	Kundu and Dutta [12]
To enhance students' knowledge and understanding of climate change by hands-on application of image processing techniques to NASA data	Based on NASA data	Geospatial technology tools and remote sensing	While the courses focused on remote sensing technology and image processing as applied to Earth, Atmospheric, and ocean sciences, these technologies have broader applicability	Cox et al. [20]

The authors of another study proposed a novel technique for wildlife identification and an introduction to pipeline tracking and precise wildlife counting [14]. Deep convolutional neural network, edge computing, and online tracking techniques were used in a field test to demarcate the population viscosity of deer in a precise location. A municipal authority supplied the site's location for this purpose. It was chosen because deer were known to be present. Identification and a precise count are part of their process. Wireless interface connection daemon is a device that includes an edge computer for interconnectivity, an infrared floodlight, a motion detection sensor, and a camera. Wireless interface connection daemon can be monitored, thanks to the solar-powered arrangement remotely. Identifying deer candidates in each video frame is the first stage. This phase is also required for "tracking by detection" using object tracking technologies. The rationale for this is that they perform better than traditional feature-based detectors that are hand-engineered. These algorithms use boundary boxes to forecast the position of interested candidates and subsequently identify them as real or fake. Deep neural networks require a lot of data to train because they are data-driven. Such models include a large number of processing layers, enabling them to learn data representations at many levels of abstraction. To increase the accuracy of the detector, a vast amount of data and a neural network capable of incorporating massive data are needed. For detection and identification, they applied YOLO v3. Using manually gathered image data, the system was trained. After that, boundary boxes were drawn around the object of interest, in this example a deer, to label the data.

Another research explores LULC changes in Rize, North-East Turkey, using RS and GIS. For this purpose, Landsat photographs spanning from 1976 and 2000 were first subjected to a supervised classification approach [17]. With an remote sensing error of fewer than 30 m, the Landsat 2000 image was georeferenced to the map. The 1976 Landsat image was georeferenced to the 2000 image with an error of less than 80 m. Radiometric corrections and systematic inaccuracies were removed from the dataset suppliers. The study defined the LULC classes of agriculture, bare soil, coniferous, deciduous, pasture, urban, and water. Using ground truth information acquired from aerial photos taken in 1973 and 2002, the maximum likelihood technique is used to categorize seven reflective bands of two Landsat images. According to these studies, the increase of farming areas predominantly leads to deforestation, suggesting that some of the region's forest areas have been cleared and turned into tea gardens. The majority of the lands that have been used for agriculture are covered in deciduous vegetation. Particularly, in the densely populated coastal areas, these lands were converted into tea fields. On the other hand, the areas that have been converted to the deciduous class primarily belong to the agricultural, coniferous, and pasture land classes. This transformation specifically happened in tea farms in rural areas as a result of the migration to the city. Due to the growth of the beaches brought on by filling materials between 1976 and 2000, some sites in these regions encountered bare earth. Similarly, the overlapping areas were projected to be substantially smaller because residential areas were constructed on lands that were determined to be bare soil in stream banks in 1976.

According to the research by Guptha et al. [21] using RS modeling, the threat posed by CC would be bigger than that posed by urbanization. The study emphasizes the importance of readily available RS datasets that, particularly in developing countries, fill the gap created by the dearth of ground-based datasets at the necessary resolutions.

A total of 5596 photos were captured during the road inspection using cameras [18]. The data were collected during an 8-year period during which there were modest infrastructural modifications that had no bearing on the investigation. The automated picture classification with TensorFlow framework and GIS analysis was used to generate animal and preserve human boundaries for the study. Two artificial neural network (ANN) models were created to identify fences and collision barriers differently to recognize fences and barriers. The image was captured from two cameras in the car located on the front left and front right. Based on this, they have manually classified the right and left images for fences and barriers. From the collected image, it was used for training purposes, validation, and testing ANN in ratios of 80%, 10%, and 10%, respectively. In training, data left and right images are shuffled alternatively. During the training, they found that the image taken from the left-hand side was not good in resolution as the car was riding on the right side. So they decided to consider the right side image due to its high quality and ability to get a classification. GIS model was developed by importing images to ArcGIS. Approximately, 20 m of distance is required between two images to get information about the absence or presence and the crash barrier. This information about the barrier's length, presence, and absence is given as barrier = 1 ("available") and fence = 1 separately for the fence. From the data, 64% of the road was accomplished by the crash barrier, and around a percent of roads were protected by fences. A total of the 1571 accidents happened in these sections of the road, 776 were in the section with barriers and 795 were in the section without barriers. But seeing the number of WVCs per length, it was evident that the section without a barrier had 2.11 times higher value than the section with the barrier. This shows that barrier has an impact on accidents. Fences have also been shown to increase the risk of WVCs by a factor of 3.08, with the area without fences having a 0.32 times lower probability of accidents. Crash barriers tend to be more effective at deterring badgers and foxes. For the area's large deer population, however, street segments without crash barriers have a two-fold higher (2.16) probability of accidents than portions with crash barriers. Smaller species, such as rabbits and "others," appear to be fully unaffected by fences, according to the rabbit counts. ANN result has a classification rate of 92% for crash barriers and 63% for fences rate. Seeing the low classification of the fences can be because the low-quality fences result in fragile structures of fence result in different resolutions of the image. There was much misclassification by both side cameras during the training data stemming. But from the resulted data, we can classify those crash barriers are significantly better than those for fences.

The roads that connect various habitat areas throughout the terrain are known as wildlife corridors. In the past, mixed integer programming models have been used to design wildlife corridors, but they are unable to regulate the geometry of the corridors. It suggests a strategy that takes corridor geometry – such as width and length – into account and controls it using path planning methods from artificial intelligence. The approach enables the user to regulate and optimize the geometric properties of wildlife corridors by fusing path design and network optimization. Increasing biodiversity is the primary objective of habitat corridor implementation. Population numbers become unstable when land parcels are fragmented by human activity, and many plant and animal species face extinction [19]. Disease, fire, predators, exotic species, domestic animals, and poachers could all benefit from the corridor's connection. It is best if the corridor is as long as feasible. The width of the corridor varies depending on the habitat type and target species, but a minimum of 1000 feet is recommended (but larger if possible).

The goal of the experiment was to demonstrate how very high-resolution space-borne data could be utilized to construct large-scale coral reef habitat maps, and how these maps could subsequently be used to support decisions regarding the management of Kenya's small-scale coral reef fisheries [22].

The many activities designed and their applications in three separate geography classrooms are described and discussed in this article. The report concentrates on the outcomes of specific lessons that aid students in analyzing Earth systems using satellite data. Several satellite institutions track the vast spectrum of radiation radiated from both the Sun and the Earth. In addition to Tint, NASA has launched a slew of satellite devices to track changes in the Earth's atmosphere. The Stat front these instruments has also been used in this investigation [20]. The following seven tutorials were created to help students develop fundamental abilities that they may use in their final projects.

Using data acquired by sensors attached to agricultural gear, precision farming strives to lower cultivation costs, improve control, and increase resource efficiency. RS has been shown to be the most effective method for identifying long-term desertification and vegetation changes. The NOAA AVHRR-derived Normalized Difference Plant Index is a well-established tool for tracking long-term changes in vegetation cover. To detect climate-induced desertification in Rajasthan's Churu district, two markers of desertification have been chosen: long-term rainfall and the RS-based indicator NDVI. Monthly rainfall data for the growing season were gathered from several rain gauge stations around the Churu area. The mean rainfall for the growing season was calculated by averaging the rainfall of different months throughout the growing season for each rain gauge station. The correlation coefficients between integrated NDVI and mean rainfall were derived from the regression analysis after preparing the database for the analysis [12].

3. Issues

Agriculture in India has been impeded by a lack of resources, small land holdings, and a lack of agro-technological understanding. GIS technology is often thought of as a costly piece of software. As a result, small-scale consumers have a hard time justifying their use. The cost outweighs the potential profits. Data interpretation in RS can be challenging. We need to know how the equipment obtains measurements in theory. Measurement uncertainties must be understood [23].

Slow tracking and scale variation are drawbacks. The extraction and analysis of the training samples from the broad search region lead to intensive calculations using test data from the next frame, which is the main cause of delayed tracking. It can improve the search approach in the future by introducing weighted features, which give higher weights to features that pertain to the item and the predicted next position. One expected effect of corridors is to synchronize populace elements and improve the probability of metapopulation eradication. Populaces that are associated by corridors could have comparative changes in overflow and, in this manner, be more defenseless against an adversarial occasion like unsettling influence or intrusion. A corridor's availability may likewise help the spread of undesirable visitors, including illness, fire, hunters, intrusive species, vaults spasm creatures, and poachers. The existing data delivered by the satellite equipment have limited information richness for runny applications. As a result, it is desirable and planned to deploy new sensors with expanded capabilities. Similarly, there are not enough satellite-based lidars and radars. In a complicated environment, no single sensor can offer entire information about a targeted object. During the calculations for the WVC, we have calculated the wild bird accident effect on the crash, but fences or barrier does not have any impact on the wild bird crash. Some sections in the fence have short sections, which can also affect the analysis as an animal can circumvent it. The different fences were not distinguished while calculating. This could also affect the result as the different types might retain different spices.

4. Bibliometric Analysis

The famous Scopus database was used for related documents search on remote sensing and climate change. Different sets of keywords were used (like "climate," "ecology," "wildlife," "wildlife preservation") with "remote sensing" word to stimulate the search on Scopus as Figure A2 and A3 show. However, the maximum documents (459 numbers) were found with the combination of words like "remote sensing" and "climate" as the article title. The search was made on December 1st, 2022. However, one article of 2023 was excluded from this list. The file was downloaded as.csv file for further usage in bibliometric analysis by R-studio Biblioshiny tool. The total numbers of 458 documents were used for the study (Supplementary image), from 243 sources, by 1815 authors in last 48 years (1974–2022), with 1148 authors keywords. Figure 1 shows the annual publication rate in this "remote sensing" and "climate" research domain. From 2014, a sharp increase can be seen in publication in "remote sensing application to save climate." Figure 2 shows the most relevant sources in this "remote sensing" and

Figure 1
Annual publication rate in this "remote sensing" and "climate" research domain

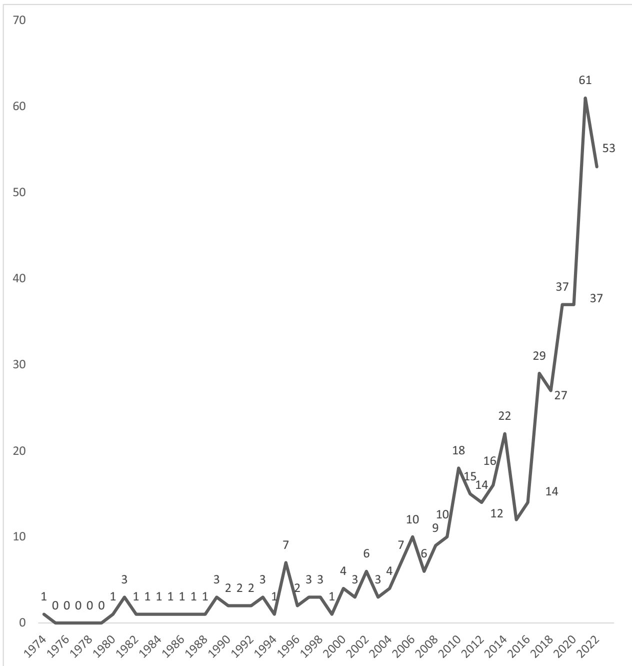


Figure 2
Most relevant sources in this "remote sensing" and "climate" research domain

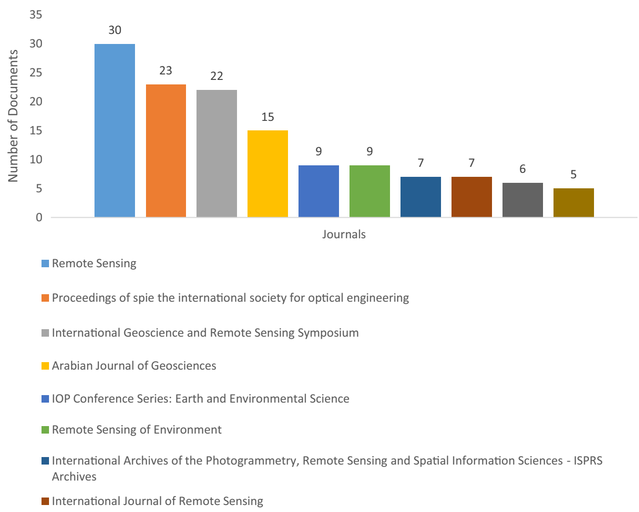
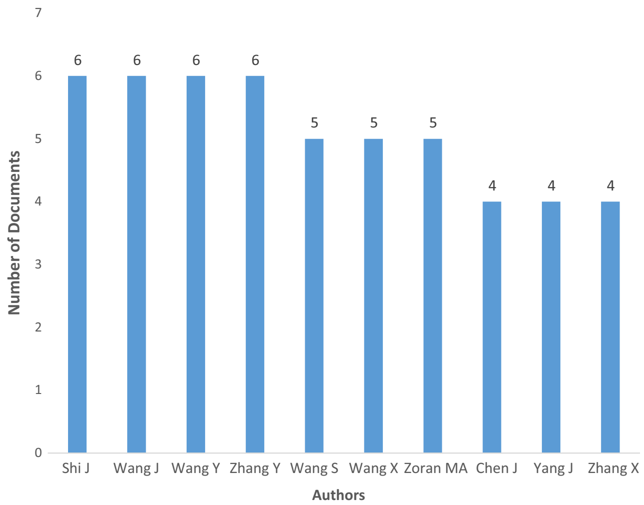


Figure 3
Most relevant authors in this "remote sensing" and "climate" research domain



"climate" research domain. RS journal is the top among these all with total 30 publications. Figure 3 shows the most relevant authors in this "remote sensing" and "climate" research domain. Shi, J, Wang, J, Wang, Y, and Zhang, Y owned six publications each in this domain. Figure 4 shows the collaboration network of authors in this "remote sensing" and "climate" research domain; it was created by VOSviewer software. Figure 5 shows the most relevant affiliations in "remote sensing" and "climate" research domain. Beijing and Columbia University are top publishing institutes (30 documents each) in this domain. Figure 6 shows the most cited countries in "remote sensing" and "climate" research domain. The most developed country like United States (3206 citations) is reported most front stepped toward application of RS to save climate risks. The other top-cited countries are Canada (2026), Germany (1062), China (943), and UK (278). The developed countries are forwarded in this domain in the world. Figure 7 shows the most co-occurred

Figure 4
Collaboration network of authors in this "remote sensing" and "climate" research domain

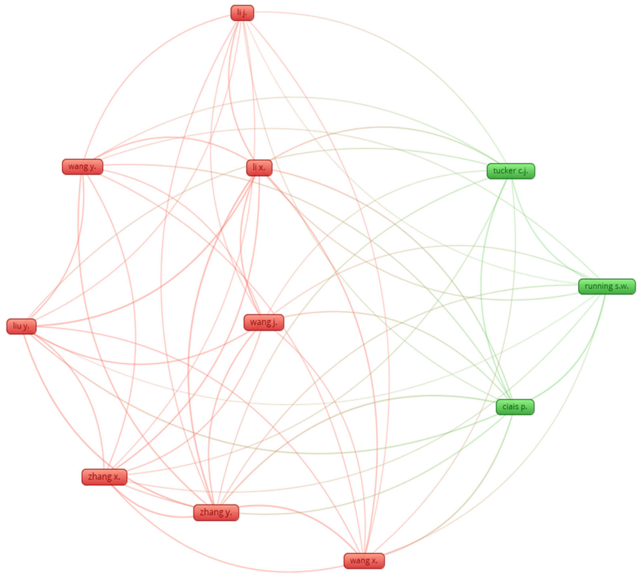
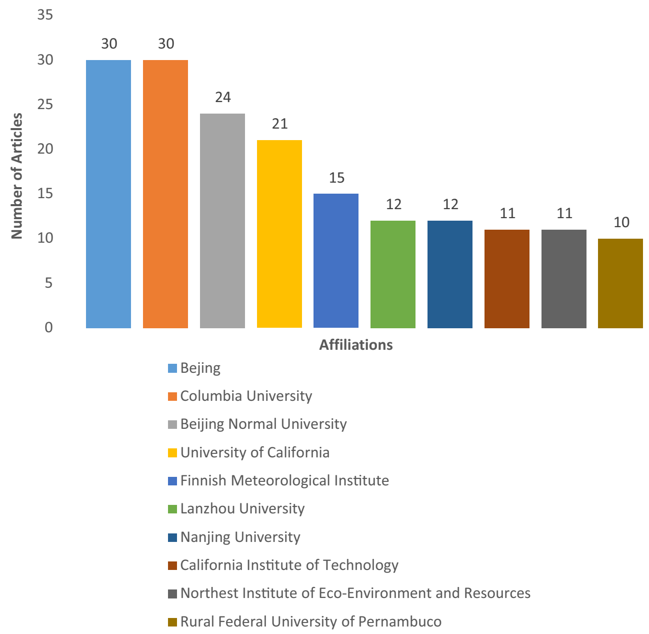


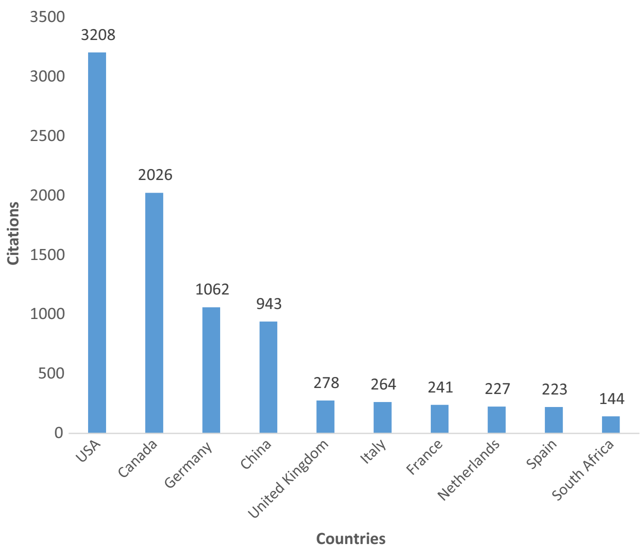
Figure 5
Most relevant affiliations in "remote sensing" and "climate" research domain



words like RS, ecosystem, ecology, CC, vegetation, satellite imaginary, and climate model in "remote sensing" and "climate" research domain.

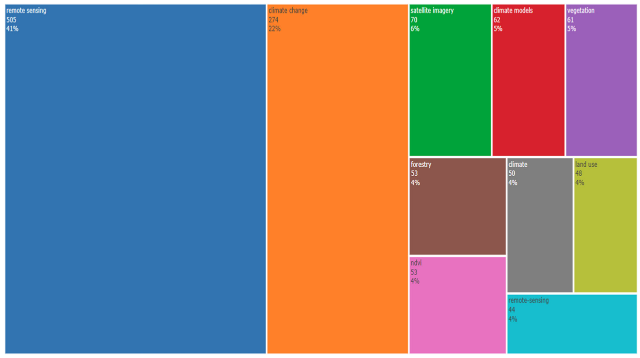
Table 2 shows the most cited documents in the research domain. "Thermal remote sensing of urban climates" article received highest citations in this research domain authored by Voogt and Oke [24] from the University of Western Ontario, Canada. In this article, the discussion was made on the use of urban thermal RS in the investigation of urban climate. It also

Figure 6
Most cited countries in "remote sensing" and "climate" research domain



entailed that the influential articles in this field have been published from developed countries like USA, Canada, and Germany. The developing countries also need to adapt the RS–GIS techniques to reduce climate risks and wild life preservation to achieve sustainability.

Figure 7
Most co-occurred words in "remote sensing" and "climate" research domain (generated via Biblioshiny)



5. Conclusion and Recommendations

Variations in ambient temperature have the greatest influence on livestock productivity and animal welfare among all climatic factors. Joy et al. [30] entailed the possible method to counteract CC and lessen its effects on small ruminant production and welfare is the selection of thermotolerant breeds through the identification of genetic features for adaptation to extreme environmental conditions. To achieve net zero and to save wild animals, minimizing climate risks is of utmost important with adopting artificial intelligence techniques [31].

Table 2
Six most cited documents in "remote sensing" and "climate" research domain

Title	Journal	Total citations	TC per year	First author	Affiliation	Country	Year
Thermal remote sensing of urban climates [24]	*Remote Sensing of Environment*	1850	92.50	J.A. Voogt	University of Western Ontario	Canada	2003
Thermal infrared remote sensing for urban climate and environmental studies: Methods, applications, and trends [25]	*ISPRS Journal of Photogrammetry and Remote Sensing*	803	57.36	Qihao Weng	Indiana State University	USA	2009
Reduction of ecosystem productivity and respiration during the European summer 2003 climate anomaly: a joint flux tower, remote sensing, and modeling analysis [26]	*Global Change Biology*	416	26.00	M. Reichstein	Max Planck Institute for Biogeochemistry	Germany	2007
Thermal remote sensing of surface soil water content with partial vegetation cover for incorporation into climate models [27]	*Journal of Applied Meteorology and Climatology*	365	13.04	Robert R. Gillies	The Pennsylvania State University	USA	1995
Global estimates of evapotranspiration for climate studies using multi-sensor remote sensing data: Evaluation of three process-based approaches [28]	*Remote Sensing of Environment*	339	28.25	Vinukollu, R. K.	Princeton University	USA	2011
Climate and infectious disease: Use of remote sensing for detection of *Vibrio cholerae* by indirect measurement [29]	*Applied Biological Sciences*	330	14.35	Brad Lobitz	California State University	USA	2000

Future studies will directly link these changes to climate at monthly or annual time increments as well as to more precise classifications of land cover. A more thorough consideration of habitats, ecosystem services, and human usages is anticipated to result from integrating habitat maps created from remotely sensed data into decision support systems. Due to its capacity to rapidly and frequently cover huge areas while providing spatial and temporal information crucial for long-term soil and crop management, RS of soil and crop can be an alluring substitute for conventional field scouting methods. Evapotranspiration estimation is necessary for the water and energy balance calculations, irrigation planning, reservoir water losses, runoff forecast, meteorology, and climatology. RS technology helps in the creation of weed maps and makes it possible to identify weed infestations in agricultural stands by locating weeds based on variations in the spectral reflectance characteristics of weeds and crops. New sensors with enhanced capabilities need to be installed. The number of satellite-based lidars and radars needs to be raised. And there is a need to explore synergies of complementary observations. RS and GIS should be used for larger areas. This would decrease the total cost of the project. Artificial intelligence should be used in determining the sensor to be used, its calibration, platform which will transport the sensor, and when the data should be collected. The data should be continuously updated to get accurate results.

Due to how infrastructure changes over time and how long the relevant time series have been available, future growth of the built environment at and along a street must be taken into account. Adding spatiotemporal data will make this more complicated from a GIS perspective. Lack of documentation for these structures is a problem because it limits the availability of data. Daily reports of incidents are made, but only in response to inspection intervals may infrastructure adjustments be taken into account. The future study should also take into account other types of obstacles, such as noise barriers, dams, and hill intersections with steep slopes, walls, or gullies, as these may have an effect on animal behavior and movement patterns, and consequently on the likelihood and hazard of WVC. These structures are also unrecorded and can only be inferred in part from images. To give the crucial information, inspection images and laser scanning data may be merged together. Then, different sorts of infrastructure could use the provided techniques. The bibliometric analysis showed research trend in this domain, such as publication rate, most stressed words by scientific community, and most influential authors and articles in research community. The study entailed that the most developed nation, like the United States (3206 citations), is said to have taken the lead in using RS to reduce climate concerns. Hence, developing countries needs to explore more scientific study toward the usage of RS to mitigate climate risks and to save wildlife. To achieve sustainability, developing nations must also embrace RS–GIS approaches to lower climatic risks and preserve wild life. Finally, RS and GIS both are application of IOT and way to move for Industry 4.0 applications.

Ethical Statement

This study does not contain any studies with human or animal subjects performed by the author.

Conflicts of Interest

The author declares that she has no conflicts of interest to this work.

Data Availability Statement

Data are available from the corresponding author upon reasonable request.

Author Contribution Statement

Arpita Ghosh: Conceptualization, Methodology, Software, Validation, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration.

References

[1] Al Sayah, M. J., Abdallah, C., Khouri, M., Nedjai, R., & Darwich, T. (2021). A framework for climate change assessment in Mediterranean data-sparse watersheds using remote sensing and ARIMA modeling. *Theoretical and Applied Climatology*, *143*(1), 639–658. https://doi.org/10.1007/s00704-020-03442-7

[2] Cui, X., Guo, X., Wang, Y., Wang, X., Zhu, W., Shi, J., . . . , & Gao, X. (2019). Application of remote sensing to water environmental processes under a changing climate. *Journal of Hydrology*, *574*, 892–902. https://doi.org/10.1016/j.jhydrol.2019.04.078

[3] Jiang, L., Huang, X., Wang, F., Liu, Y., & An, P. (2018). Method for evaluating ecological vulnerability under climate change based on remote sensing: A case study. *Ecological Indicators*, *85*, 479–486. https://doi.org/10.1016/j.ecolind.2017.10.044

[4] Paul, S. S., Coops, N. C., Johnson, M. S., Krzic, M., Chandna, A., & Smukler, S. M. (2020). Mapping soil organic carbon and clay using remote sensing to predict soil workability for enhanced climate change adaptation. *Geoderma*, *363*, 114177. https://doi.org/10.1016/j.geoderma.2020.114177

[5] Yang, J., Gong, P., Fu, R., Zhang, M., Chen, J., Liang, S., . . . , & Dickinson, R. (2013). The role of satellite remote sensing in climate change studies. *Nature Climate Change*, *3*(10), 875–883. https://doi.org/10.1038/nclimate1908

[6] Dash, S. P., Dipankar, P., Burange, P. S., Rouse, B. T., & Sarangi, P. P. (2021). Climate change: How it impacts the emergence, transmission, resistance and consequences of viral infections in animals and plants. *Critical Reviews in Microbiology*, *47*(3), 307–322. https://doi.org/10.1080/1040841X.2021.1879006

[7] Lacetera, N. (2019). Impact of climate change on animal health and welfare. *Animal Frontiers*, *9*(1), 26–31. https://doi.org/10.1093/af/vfy030

[8] Schleuning, M., Neuschulz, E. L., Albrecht, J., Bender, I. M., Bowler, D. E., Dehling, D. M., . . . , & Kissling, W. D. (2020). Trait-based assessments of climate-change impacts on interacting species. *Trends in Ecology & Evolution*, *35*(4), 319–328. https://doi.org/10.1016/j.tree.2019.12.010

[9] Bryndum-Buchholz, A., Tittensor, D. P., Blanchard, J. L., Cheung, W. W., Coll, M., Galbraith, E. D., . . . , & Lotze, H. K. (2019). Twenty-first-century climate change impacts on marine animal biomass and ecosystem structure across ocean basins. *Global Change Biology*, *25*(2), 459–472. https://doi.org/10.1111/gcb.14512

[10] Shakoor, A., Shakoor, S., Rehman, A., Ashraf, F., Abdullah, M., Shahzad, S. M., . . . , & Altaf, M. A. (2021). Effect of animal manure, crop type, climate zone, and soil attributes on greenhouse gas emissions from agricultural soils—A

global meta-analysis. *Journal of Cleaner Production*, *278*, 124019. https://doi.org/10.1016/j.jclepro.2020.124019

[11] Radchuk, V., Reed, T., Teplitsky, C., van de Pol, M., Charmantier, A., Hassall, C., . . . , & Kramer-Schadt, S. (2019). Adaptive responses of animals to climate change are most likely insufficient. *Nature Communications*, *10*(1), 3109. https://doi.org/10.1038/s41467-019-10924-4

[12] Kundu, A., & Dutta, D. (2011). Monitoring desertification risk through climate change and human interference using remote sensing and GIS techniques. *International Journal of Geomatics and Geosciences*, *2*(1), 21–33.

[13] Obeidavi, Z., Rangzan, K., Kabolizade, M., & Mirzaei, R. (2019). A web-based GIS system for wildlife species: A case study from Khouzestan Province, Iran. *Environmental Science and Pollution Research*, *26*(16), 16026–16039. https://doi.org/10.1007/s11356-019-04616-1

[14] Arshad, B., Barthelemy, J., Pilton, E., & Perez, P. (2020). Where is my deer?-Wildlife tracking and counting via edge computing and deep learning. In *2020 IEEE Sensors*, 1–4. https://doi.org/10.1109/SENSORS47125.2020.9278802

[15] Numbere, A. O. (2022). Application of GIS and remote sensing towards forest resource management in mangrove forest of Niger Delta. In M. K. Jhariya, R. S. Meena, A. Banerjee & S. N. Meena (Eds.), *Natural resources conservation and advances for sustainability* (pp. 433–459). Elsevier. https://doi.org/10.1016/B978-0-12-822976-7.00024-7

[16] Zafar, T. B., Ding, W., Din, S. U., Khan, G. M., Hao, C., & He, L. (2021). Forest cover and land use map of the Chunati Wildlife Sanctuary based on participatory mapping and satellite images: Insight into Chunati beat. *Land Use Policy*, *103*, 105193. https://doi.org/10.1016/j.landusepol.2020.105193

[17] Reis, S. (2008). Analyzing land use/land cover changes using remote sensing and GIS in Rize, North-East Turkey. *Sensors*, *8*(10), 6188–6202. https://doi.org/10.3390/s8106188

[18] Pagany, R., & Dorner, W. (2019). Do crash barriers and fences have an impact on wildlife–vehicle collisions?—An artificial intelligence and GIS-based analysis. *ISPRS International Journal of Geo-Information*, *8*(2), 66. https://doi.org/10.3390/ijgi8020066

[19] St John, R., Tóth, S. F., & Zabinsky, Z. B. (2018). Optimizing the geometry of wildlife corridors in conservation reserve design. *Operations Research*, *66*(6), 1471–1485. https://doi.org/10.1287/opre.2018.1758

[20] Cox, H., Kelly, K., & Yetter, L. (2014). Using remote sensing and geospatial technology for climate change education. *Journal of Geoscience Education*, *62*(4), 609–620. https://doi.org/10.5408/13-040.1

[21] Guptha, G. C., Swain, S., Al-Ansari, N., Taloor, A. K., & Dayal, D. (2021). Evaluation of an urban drainage system and its resilience using remote sensing and GIS. *Remote Sensing Applications: Society and Environment*, *23*, 100601. https://doi.org/10.1016/j.rsase.2021.100601

[22] Maina, J. M., Jones, K. R., Hicks, C. C., McClanahan, T. R., Watson, J. E., Tuda, A. O., & Andréfouët, S. (2015). Designing climate-resilient marine protected area networks by combining remotely sensed coral reef habitat with coastal multi-use maps. *Remote Sensing*, *7*(12), 16571–16587. https://doi.org/10.3390/rs71215849

[23] Kingra, P. K., Majumder, D., & Singh, S. P. (2016). Application of remote sensing and GIS in agriculture and natural resource management under changing climatic conditions. *Agricultural Research Journal*, *53*(3), 295–302. https://doi.org/10.5958/2395-146X.2016.00058.2

[24] Voogt, J. A., & Oke, T. R. (2003). Thermal remote sensing of urban climates. *Remote Sensing of Environment*, *86*(3), 370–384. https://doi.org/10.1016/S0034-4257(03)00079-8

[25] Weng, Q. (2009). Thermal infrared remote sensing for urban climate and environmental studies: Methods, applications, and trends. *ISPRS Journal of Photogrammetry and Remote Sensing*, *64*(4), 335–344. https://doi.org/10.1016/j.isprsjprs.2009.03.007

[26] Reichstein, M., Ciais, P., Papale, D., Valentini, R., Running, S., Viovy, N., . . . , & Zhao, M. (2007). Reduction of ecosystem productivity and respiration during the European summer 2003 climate anomaly: A joint flux tower, remote sensing and modelling analysis. *Global Change Biology*, *13*(3), 634–651. https://doi.org/10.1111/j.1365-2486.2006.01224.x

[27] Gillies, R. R., & Carlson, T. N. (1995). Thermal remote sensing of surface soil water content with partial vegetation cover for incorporation into climate models. *Journal of Applied Meteorology and Climatology*, *34*(4), 745–756. https://doi.org/10.1175/1520-0450(1995)034<0745:TRSOSS>2.0.CO;2

[28] Vinukollu, R. K., Wood, E. F., Ferguson, C. R., & Fisher, J. B. (2011). Global estimates of evapotranspiration for climate studies using multi-sensor remote sensing data: Evaluation of three process-based approaches. *Remote Sensing of Environment*, *115*(3), 801–823. https://doi.org/10.1016/j.rse.2010.11.006

[29] Lobitz, B., Beck, L., Huq, A., Wood, B., Fuchs, G., Faruque, A. S. G., & Colwell, R. (2000). Climate and infectious disease: Use of remote sensing for detection of *Vibrio cholerae* by indirect measurement. *Proceedings of the National Academy of Sciences*, *97*(4), 1438–1443. https://doi.org/10.1073/pnas.97.4.1438

[30] Joy, A., Dunshea, F. R., Leury, B. J., Clarke, I. J., DiGiacomo, K., & Chauhan, S. S. (2020). Resilience of small ruminants to climate change and increased environmental temperature: A review. *Animals*, *10*(5), 867. https://doi.org/10.3390/ani10050867

[31] Das, A., & Ghosh, A. (2023). Vision net zero: A review of decarbonisation strategies to minimise climate risks of developing countries. *Environment, Development and Sustainability*, *27*(10), 23665–23701. https://doi.org/10.1007/s10668-023-03318-6

How to Cite: Ghosh, A. (2023). Applications of Remote Sensing as Climate Resilience Technique: A Bibliometric Research Trends Analysis. *Green and Low-Carbon Economy*. https://doi.org/10.47852/bonviewGLCE32021242

Appendix:

Figure A1
Applications in remote sensing & GIS

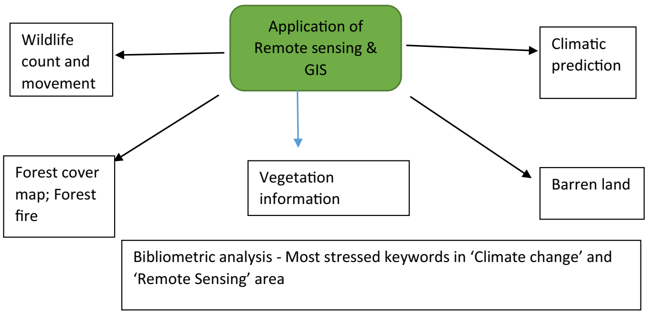


Figure A2
Cloud keywords in "climate change" and "remote sensing" areas

Figure A3
Main information about the Scopus (.csv) imported file