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Color Image Segmentation Optimization: Threshold Edge Detection with Harmonic and Wiener Filter Enhancements

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Abstract: Digital photos can be segmented to find objects, borders, and other relevant information. Segmentation can be done in a variety of ways, including Watershed Segmentation, Region-Based Segmentation, Edge-Based Segmentation, Threshold-Based Segmentation, and Cluster-Based Segmentation. These methods produce a segmented image, which is a compilation of every pixel in the image. Pixels represent the color, texture, and other elements of an image. An image is divided into separate objects or areas. Color Image Segmentation uses threshold-based edge detection, and it's improved through harmonic and Wiener filters to reduce noise. This method simplifies and changes the representation of an image into something (line, curve drawing that highlights the intensity change, which is more important and easier to explore. In this concept, convert a color image into a gray-scale image and apply different filters (Robert, Prewitt, Sobel, log, and Canny) with edge detection techniques. This applied edge detection technique is also useful with a filter that gives acute and exact results. This research computes the Threshold 0.67 values for color images to check for better performance. For this purpose, use MATLAB. Our technique will help to improve edge detection by the combination of other types of filters, namely Hormonic and Weiner, to eliminate the noise from the image.

Keywords: Image Segmentation; Edge Detection; Threshold; Harmonic Filter; Weiner Filter

1. Introduction

In the 21st century, computer technology is used in different fields of life. Mostly, researchers are working on different projects according to applications. If we discuss photography concepts taken from different sources (satellite, closed circuit television camera, X-rays, Digital Single-Lens Reflex, etc.), etc [1]. In this concept, we interact with Images. Computer vision involves the recognition and classification of objects in an image. So we are going for detailed Digital image processing [2]. Image processing techniques have five steps, which are image acquisition (physical Scene), image pre-processing (operation with images), image segmentation, image post-processing (image editing in photography), and image analysis [3]. The most important step in image processing is Image segmentation. Image segmentation is the process of dividing an image into distinct parts, known as segments. The basic applications are medical imaging, face diagnosis, fingerprint recognition, and locating objects in satellite images (roads, forests, etc). Image segmentation can be arranged into two types: local segmentation (it shows the region of interest of a specific portion) and global segmentation (it shows the whole image of interest, which has larger connectivity of pixels). The image segmentation approaches can be arranged into two types based on the

properties of the image. Discontinuity detection-based approach (point, line, and edge detection) and similarity detection-based approach (Thresh holding, region growing, region splitting, and merging [4].

The basic features of any image are edges. Edge can be defined as joined pixel that is found on the boundary of the region is called an Edge. Edges can be arranged as step edge (Sudden change in intensity level), Roof edge (not direct across a short distance), ramp edge (slow change in intensity), and spike edge (rapid change in intensity) [5]. Edge detection is the technique of discovering and identifying abrupt discontinuities in an image. The four steps of Edge Detection are localization, detection, enhancement, and filtering. The edge detection techniques employed in this paper include the Sobel, Prewitt, Robert, Canny, and Laplacian of Gaussian Wavelet edge detector approaches [6]. To detect crisp and accurate edges that are not achievable with the current technology, a novel edge detection method is planned. By adding more filter types—such as Weiner, STD, harmonic, and geometric filters—that eliminate image noise [7], this edge detection technique will be improved. A novel method that expands in image segmentation of color images employing the Threshold Based Edge Detection Algorithm, and filters through this, we get better results. Thresholding is the process of splitting an image into binary form using the gray level distribution. It segments the image into the foreground (lighter object) and background. The basic standard of thresholding is set to a luminance or color intensity threshold, and comparing each pixel (a, b) of an image f(a,b) with T. If the pixel value is larger than T value, then that pixel is 255, then the point is called an object point. If the pixel value is less than the T value, then the pixel will be black, and that point is called the background. When the T value is fixed over the whole image, the process is called Global Thresholding. If the T value changes over an image, then this process is called Variable Thresholding [8].

2. Related Work

A lot of work is done on digital image segmentation using edge detection techniques. Many researchers' works on discontinuities of images, so for better performance, they apply different filters with times and show better results. They also apply these methods in the medical field (Skin cancer, Breast Cancer, Blood Cells, Brain tumor). Some researchers work on a comparative study of filters or edge detection techniques, and some work on-road vehicle detection. Many methods are applied for image segmentation, such as Canny, Robert, Prewitt, Sobel, Watershed, and. Threshold is the most popular technique. To improve techniques, the researcher gives many theories for image Segmentation.

According to this, various image segmentation techniques are compared for different medical images. These techniques are prominent for a large number of medical applications. All these methods help with object detection. They mention in the paper that no one method is suitable for every image, and not all techniques are suitable for a particular image [9]. Kunal Gupta worked on a Comparative study on edge detection techniques. Implementation of different filters on images with discontinuity (edge detection) concludes a result that the 1st order derivative does not perform well, while the 2nd order derivative gives better results in edge detection scenes [10]. The authors worked on a threshold-based edge detection Algorithm. It is stated that image segmentation based on discontinuities (Edge Detection) produces different outcomes. During the implementation of different previous filters (Edge Detection), it was concluded that the canny filter produced the best result, and further, other noisy removal filters were used, like Harmonic, which produced better performance. It also applies different thresholding values for better results [11].

Bhargavi worked on image segmentation and especially used the Thresholding of different techniques. According to this, thresholding is a non-contextual method that accepts a threshold value to change a scale image into a binary image. It is concluded that the OSTU method is the best. This method works well but does not give good results, secondly, adaptive thresholding is a computationally cost-effective method [12].In this paper, and the author used the gradient and zero-crossing method with the example of the Shark Fish type. They applied different filters for detecting edges in images and concluded that the LOG filter produced better results in the case of noise form [13].In this paper, the author proposed a novel method for edge detection using the threshold concept. In the practical work, the author uses color images and applies different filters, and concludes that the canny filter is best. For the elimination of noise and clear results, they apply a threshold-based algorithm; they apply a 0.65 value, which shows better performance [14].Savant works on color image segmentation using a gradient operator. According to this, edge detection and different filters are applied to 50-plus images, and a comparative result. They said that

the Sobel operator's performance is better than other operators [15].A method to detect edges for any image to apply different filters for edge detection using Robert, Prewitt, and Canny filters, so apply other filters using a threshold scenario. It applies a threshold value [0-1]. According to this novel method, 0.66 is an exact value where they got the right results [16].

Author's suggested a gradient-based edge detection method called the Sobel operator. The gradient of the picture intensity function is approximated by this discrete differentiation operator. The traditional Sobel operator uses two kernels for each image, Gx and Gy, where Gx is the x-directional gradient estimation and Gy is the y-directional gradient estimation [17].

In this paper, the author works on noisy images and uses different denoising methods and combines the Sobel filter for detecting edges. After implementation, it's concluded that soft-threshold wavelet de-noising and Sobel operator give better result for edge detection [18]. According to this method, first-order derivative/gradient methods, including Roberts's operator, Sobel operator, and Prewitt operator, which show blurring performance, while in second-order derivatives, which is also called zero crossing, including method Laplacian of Gaussian which determines the sub-pixel location in the image. The last method that is used in this paper is a canny detector, which first eliminates the noise and shows better edges in the image. A canny edge filter is the most expensive computationally compared to other filters [19].

Palvi Rani proposed a hybrid method for edge detection that performs edge detection in two steps. In the first step, for picture smoothing, the canny filter is applied, and in 2nd step, NN (Neural Network) is used to observe exact edges. Since a neural network (NN) is a non-linear network with an inherent threshold capacity, it is an excellent tool for edge detection. Several training patterns can be used to train a neural network (NN) utilizing the propagation technique again, however, choosing the appropriate instruction set is the most challenging part [20].

Richard Lee proposed a method for skin cancer images. There are two types: melanoma and non-melanoma. Four features of melanoma skin cancer are described, including shape, color, diameter, and Border. After the implementation of melanoma and non-melanoma, the comparison result is displayed in which 9/10 show melanoma and 8/10 show non-melanoma skin cancer images are affected. The author also states that if the mole diameter is greater than 6 millimeters, then it gives the response of melanoma skin cancer. For better results of image segmentation, different techniques are used, but mostly for skin cancer image detection using watershed mark control and Canny edge detection applied [21].

In this paper, they have discussed existing image segmentation techniques. The author describes that image segmentation follows two approaches: discontinuity and similarity. Discontinuity shows edge detection while similarity-based detection shows region growth, splitting, and merging of regions. They also discuss theory-based segmentation, including genetic and neural network-based algorithms. In this paper, they also mention that no one image fulfills the algorithm in the situation of a problem [22].

In this paper, the author works with Robert, Prewitt, and Sobel operators. They implemented this entire operator and concluded that Robert's operation works with binary images only. Roberts shows edges in the case of abrupt change of intensity value. Robert's operating system is small, so it works fast. Sobel and Roberts show an edge in the case of average change of intensity value [23].

The author has proposed a method for satellite images. They used different methods for fuzzy edge detection, which are fuzzification, defuzzification, fuzzy inference rule (and-or), and unsharp Masking. All these techniques produce better results for sharpening images [24].

The author worked on different image segmentation techniques. Different filters are applied in this research, but the author describes that the threshold method is the most prominent among the other filters. It is simple and computationally [25].In this paper, the author describes an adaptive filter, which is used for the elimination of noise from an image, and a Gaussian filter reduces the noise from an image [26].In this paper, the author uses different image segmentation techniques, including threshold-based, PDE-based, Fuzzy theory, ANN-based segmentation, and a Hybrid Approach. After implementation, it's concluded that the Hybrid approach was best for solving the problem [27]. Studying the edge detection process using various approaches is the primary goal. For segmentation, edge detection techniques such as Roberts, Prewitt, Sobel, Log, and Canny are also employed. A novel edge detection method is put forth that can identify sharp and accurate edges that the current method is unable to. Combining this edge detection method with other filter types—such as harmonic, Weiner, and geometric filters—can enhance it by removing.

3. Proposed Model

Enhance color image segmentation using the MATLAB environment [28] by applying a filter and using a threshold-based edge detection algorithm. We apply several filters to photos to get better outcomes. The three processes of image processing—image acquisition, image analysis, and picture output—are highlighted in Figure 1's block diagram.

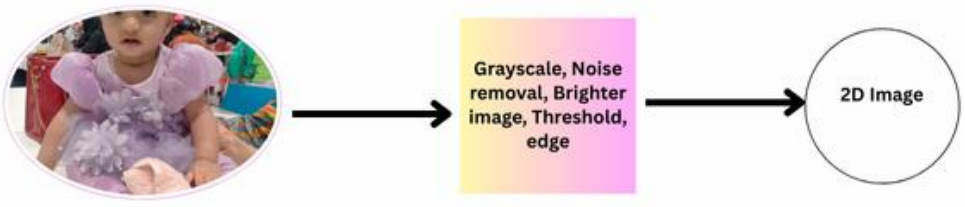

Figure 1. A 2D image processing technique's block diagram

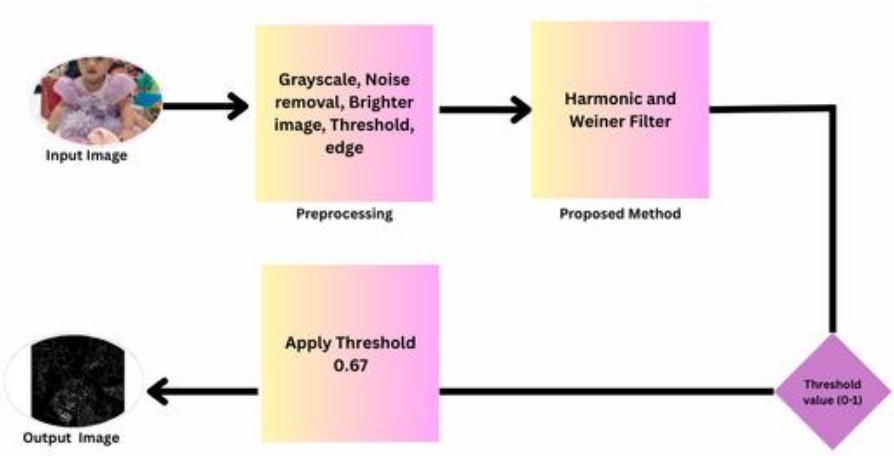

Figure 2. Proposed Model for Image Segmentation

The suggested model, which is implemented in MATLAB, is displayed in Figure 2. The suggested model used threshold values for picture contrast eliminated noise, and transformed the image to grayscale, as shown. To make decisions about which mask to choose and how to identify edges, a histogram is used. Brightness levels should be separated into several sections to assess the contrasting circumstances. In this work, the image histogram is averaged to determine the proper range for brightness levels. Unlike linear filters such as Sobel and Prewitt, the harmonic mean filter is a nonlinear filter that effectively reduces salt noise (bright pixels) while preserving edge details. Equation 1 shows the formula. This is further illustrated in Table 1.

$$\text{Harmonic Mean} = \frac{\mathbf{n}}{\sum_{\mathbf{j}}^{\mathbf{n}}=\mathbf{1}\frac{\mathbf{1}}{\mathbf{x_{j+\ni}}}} \quad (1)$$

Table 1. Harmonic Filter Overview

Aspect	Harmonic Filter
Type	Non-linear, Order-statistic filter
Best For	Removing salt noise
Image Types	Grayscale
Kernel Size	Typically 3×3, 5×5
Comparison to Wiener Filter	Harmonic is non-linear and simpler

START

Step 1: Convert a color image to a grayscale one
Step 2: Convert the image to 2D format in step two.
Step 3: Handle symmetric padding in step three.
Step 4: Start the output picture
Step 5: J to N for loop
Step 6: Assign Harmonic Means to the output conversion

Step 7: Return the Converted Picture
END

4. Simulation & Results

Figure 3 shows the results of a MATLAB-based image processing method utilizing several MATLAB-built algorithms. The results represent the output of the program used to process the photos. The outcomes represent the outcome of every operation carried out on the pictures using MATLAB's image processing toolbox, utilizing all required MATLAB command codes and algorithms.

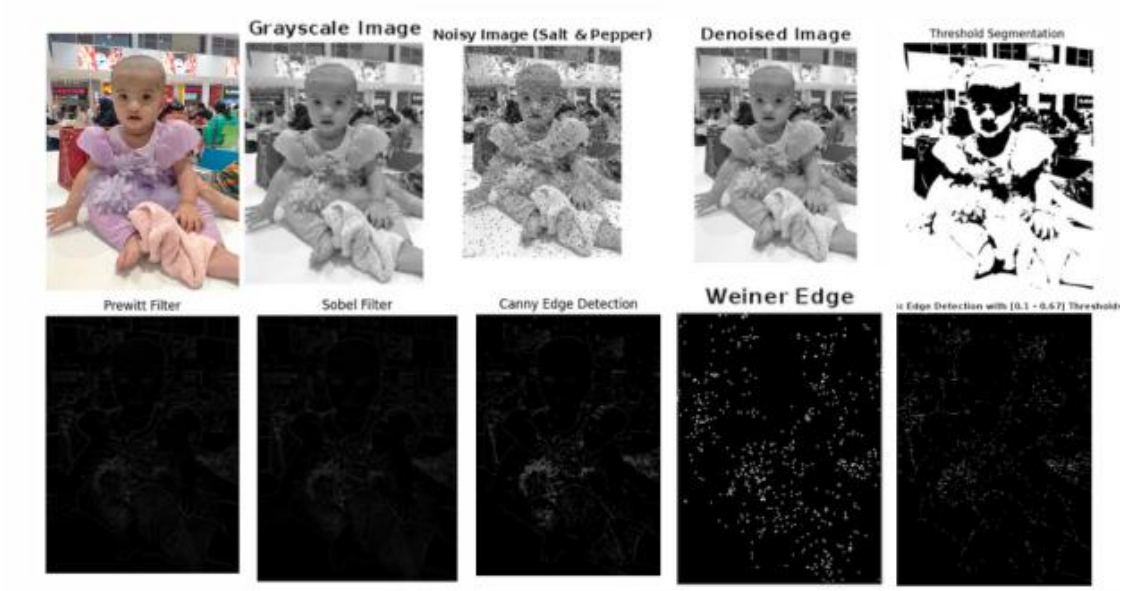

Figure 3. Comparison of the Filter using the Threshold Value

A set of image-processing techniques applied to a baby girl's photo is shown in Figure 3. A color image is first converted to grayscale to start the procedure. After that, it displays a threshold segmentation, a denoised version, and a noisy version with salt and pepper noise added. Using the Prewitt, Sobel, and Canny, and Weiner filters, edge detection is shown in the bottom row. The results of edge detection with a particular threshold of 0.67 are displayed in the final image. It is just a graphic representation of different image processing methods. Figure 4 shows the overall good edge detections with a threshold value of 0.67.

If we pass the low pass and identity filter kernel equation 2 shows :

$$H = \begin{matrix}0&0&0\\0&1&0\\0&0&0\end{matrix} - \frac{1}{9}\begin{matrix}1&1&1\\1&1&1\\1&1&1\end{matrix} = \frac{1}{9}\begin{matrix}-1&-1&-1\\-1&8&-1\\-1&-1&-1\end{matrix} \quad (2)$$

where the sum of the weights is actually zero, therefore once more we can disregard the ninth element. Pure high-pass filters often have the characteristic that the weights add up to zero.

$$S = (1-F)*I + F*H \quad (3)$$

Equation 3 shows the convolutional kernels it becomes S shows sharpen image, I is the original image, H is the high pass filter and F is the fraction between 0-1.

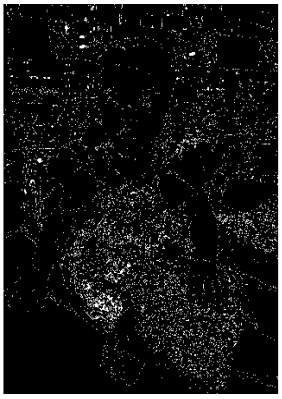

Figure 4. Harmonic Mean Edge Detection with Threshold

5. Conclusion

Our main aim is to improve segmentation by using different edge detection techniques, where previously used techniques were Robert, Prewitt, Sobel, Log of Laplacian (LOG), and Canny filters. A new edge detection technique is proposed, which will help to detect the precise and acute edges that are not possible with the previous techniques. Our technique will help to improve edge detection by the combination of other types of filters, namely Harmonic and Weiner, to eliminate the noise from the image. With the simulation threshold values, 0.67 shows a moderate mean square error, a low level, 0.0345, root mean square error 0.01, and Peak Signal-to-Noise Ratio of 30.38 dB shows a higher quality result with the given image.

References

1. Tagai, I., & Batham, D. (2024). Digital Camera: A Review and Comparative Analysis. Smart Engineering Technology and Management, 437.
2. Archana, R., & Jeevaraj, P. E. (2024). Deep learning models for digital image processing: a review. Artificial Intelligence Review, 57(1), 11.
3. Tejasree, G., & Agilandeeswari, L. (2024). An extensive review of hyperspectral image classification and prediction: techniques and challenges. Multimedia Tools and Applications, 83(34), 80941-81038.
4. Zhou, T., Xia, W., Zhang, F., Chang, B., Wang, W., Yuan, Y., ... & Cremers, D. (2024). Image segmentation in the foundation model era: A survey. arXiv preprint arXiv:2408.12957.
5. Du, H., Li, Z., Niyato, D., Kang, J., Xiong, Z., Shen, X. S., & Kim, D. I. (2024). Enabling AI-generated content services in wireless edge networks. IEEE Wireless Communications.
6. Li, H., & Xu, K. (2025). Innovative adaptive edge detection for noisy images using wavelet and Gaussian methods. Scientific Reports, 15(1), 5838.
7. Maity, A., & Chatterjee, R. (2018). Impulsive noise in images: a brief review. Computer Vision Graphics and Image Processing, 4(6-15), 1.
8. Udoy, M. R. I., Islam, M. M., Jaiswal, A., & Aziz, A. (2024, July). Sub-Micron Binary HyperPixel Sensor Circuit: In-Pixel Binarization with Variable Thresholding. In 2024 IEEE Computer Society Annual Symposium on VLSI (ISVLSI) (pp. 21-26). IEEE.
9. Pundir, S., Matta, P., & Chaudhary, S. (2024, June). Image Segmentation Techniques: Applications, Opportunities and Challenges. In 2024, 15th International Conference on Computing, Communication and Networking Technologies (ICCCNT) (pp. 1-8). IEEE.
10. Babker, A., Abbas, A., Shalabi, M., & Mohamedahmed, K. A. (2024). Edge Detection and Contrast Enhancement in the Examination of Megaloblastic Anemia Cells in Medical Images with Comparative Analysis of Different Approaches.
11. Costarellı, D., & Sambucını, A. R. (2024). A comparison among a fuzzy algorithm for image rescaling with other methods of digital image processing. Constructive Mathematical Analysis, 7(2), 45-68.
12. Chandra, N., & Bhardwaj, A. (2024). Medical image enhancement using modified type II fuzzy membership function generated by Hamacher T-conorm. Soft Computing, 28(9), 6753-6774.
13. Xian, R., Xiong, X., Peng, H., Wang, J., de Arellano Marrero, A. R., & Yang, Q. (2024). Feature fusion method based on spiking neural convolutional network for edge detection. Pattern Recognition, 147, 110112.
14. Bhuvaneshwaran, D. S., Veeraperumal, K., Rajagopal, M., Santharaman, S., & Ramasamy, P. (2025, March). Edge detection in image segmentation. In AIP Conference Proceedings (Vol. 3175, No. 1). AIP Publishing.
15. Bathini, V., & Rani, K. U. (2025). A Review of Analyzing Different Agricultural Crop Yields Using Artificial Intelligence. International Journal of Advanced Computer Science & Applications, 16(1).
16. Kumar, D., & Kukreja, V. (2024). Image segmentation, classification, and recognition methods for wheat diseases: Two Decades' systematic literature review. Computers and Electronics in Agriculture, 221, 109005.
17. Lecca, M., & Serapioni, R. P. (2025). Non-uniformly lighted image enhancement exploiting the Atangana–Baleanu fractional integral and the Sobel filter. Journal of the Optical Society of America A, 42(2), 183-192.
18. Mujahidan, M. Y. A., & Manullang, M. C. T. (2024). Pixel Intensity Tracking for Remote Respiratory Monitoring: A Study on Indonesian Subjects. arXiv preprint arXiv:2412.09938.
19. Kuriachen, B., Jeyaraj, R., Raphael, D., Ashok, P., Sundari, P. S., & Paul, A. (2025). Defect detection in fused deposition modelling using lightweight convolutional neural networks. Engineering Applications of Artificial Intelligence, 141, 109802.
20. Yuan, Y., Chen, W., Tang, J., & Yang, J. (2024, July). A High-Precision Edge Detection Algorithm Based on Improved Sobel Operator-Assisted HED. In 2024 IEEE 14th International Conference on CYBER Technology in Automation, Control, and Intelligent Systems (CYBER) (pp. 83-88). IEEE.
21. Agrawal, N., & Aurelia, S. (2024). Segmentation of Vitiligo images using modified Watershed Segmentation. Library of Progress-Library Science, Information Technology & Computer, 44(3).
22. Khan, R. U., Almakdi, S., Alshehri, M., Haq, A. U., Ullah, A., & Kumar, R. (2024). An intelligent neural network model to detect red blood cells for various blood structure classification in microscopic medical images. Heliyon, 10(4).

23. Zhang, J., Xiao, L., Zhang, Y., Lai, J., & Yang, Y. (2024). Optimization and performance evaluation of deep learning algorithm in medical image processing. Optimization, 7(3), 2024.
24. Dai, H., Yang, Y., Huang, S., Wan, W., Lu, H., & Wang, X. (2024). Pansharpening based on fuzzy logic and edge activity. IEEE Geoscience and Remote Sensing Letters, 21, 1-5.
25. Ullah, F., Kumar, K., Rahim, T., Khan, J., & Jung, Y. (2025). A new hybrid image denoising algorithm using adaptive and modified decision-based filters for enhanced image quality. Scientific Reports, 15(1), 8971.
26. Shekar, B. H., Bhat, S. S., & Shetty, R. (2024). Edge Detection in Gray-Scale Images Using Partial Sum of Second-Order Taylor Series Expansion. SN Computer Science, 5(1), 197.
27. Lei, L., Yang, Q., Yang, L., Shen, T., Wang, R., & Fu, C. (2024). Deep learning implementation of image segmentation in agricultural applications: A comprehensive review. Artificial Intelligence Review, 57(6), 149.
28. Yakaiah, P., Syambabu, V., Reddy, G. K., Sateesh, R., & Avangapuram, N. R. (2024). Brain Tumor Detection Using MATLAB and Image Processing. In Advancements in Science and Technology for Healthcare, Agriculture, and Environmental Sustainability (pp. 524-530). CRC Press.