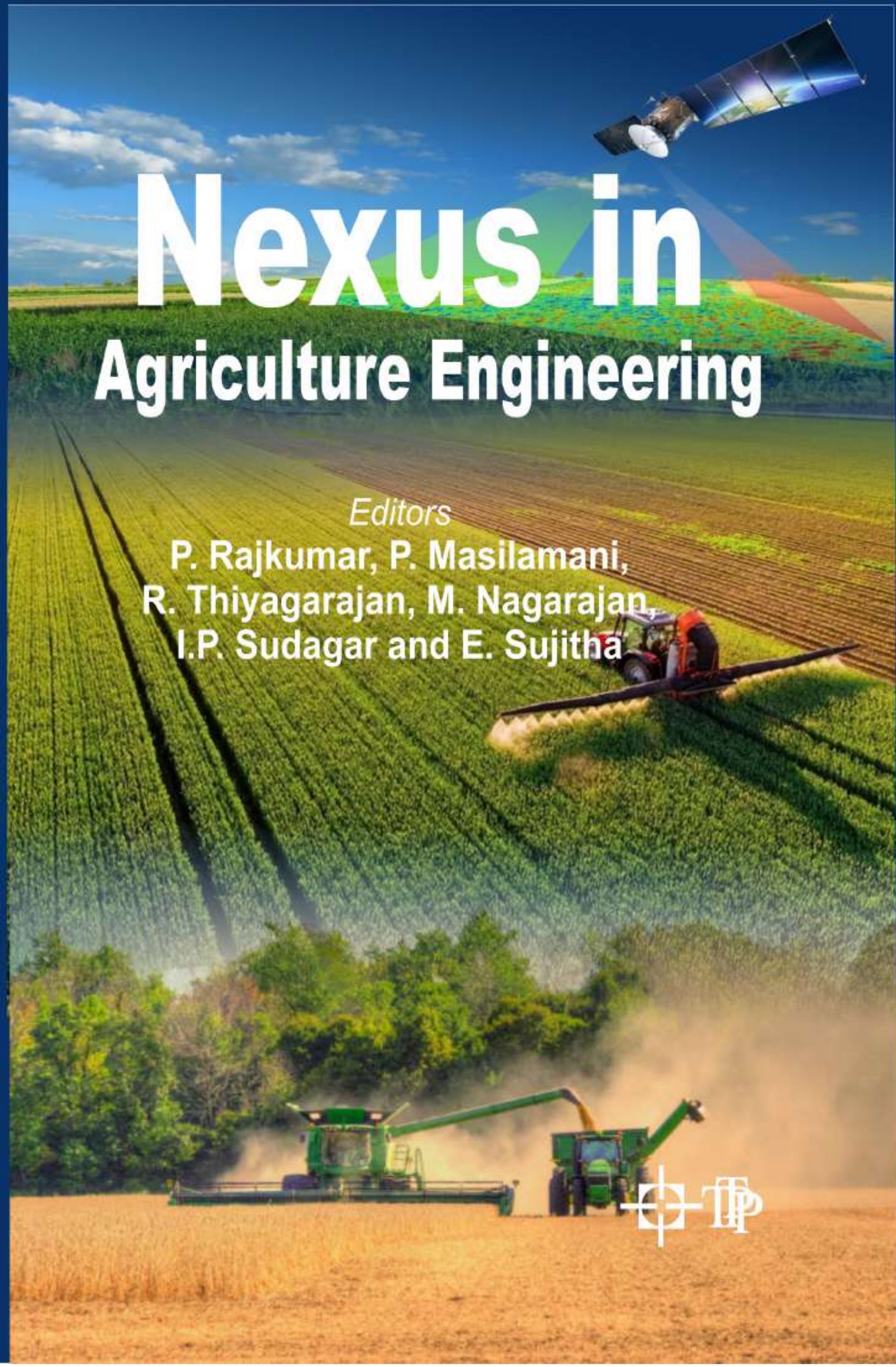

About the Book

The book "*Nexus in Agriculture – Engineering*" brings together the contributions of experienced academicians, researchers from various institutes. It covers a wide range of topics such as precision farming, farm mechanization, sustainable water management, bioenergy, food processing, and the use of advanced technologies like Artificial Intelligence (AI), Machine Learning (ML), and the Internet of Things (IoT) in agriculture.

Each chapter combines theoretical insights with practical applications, offering readers a comprehensive understanding of how modern tools and techniques can improve agricultural productivity while conserving resources. The interdisciplinary approach makes this book especially valuable for addressing the complex issues facing today's agricultural landscape.

Nexus in Agriculture - Engineering is designed for a broad audience, including researchers, educators, students, policymakers, and extension professionals. It serves as a useful resource for those seeking to implement sustainable practices and adopt technology-driven solutions in the agricultural sector.

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Dr. R. THAMIZH VENDAN, Ph.D.,
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FOREWORD

In an era of escalating environmental challenges and rising global food demands, sustainable agriculture has emerged as a critical frontier for ensuring food security, conserving natural resources, and mitigating the effects of climate change. The reference book "*Nexus in Agriculture - Engineering*" is a timely and significant contribution to the scientific community, presenting a collection of titles that delve into innovations, practices, and policies shaping the future of agriculture and agricultural Engineering.

The book compilation of chapters emphasizes a wide range of emerging trends, including precision agriculture, climate-resilient crop modelling, microbial fuel cells, nutritional innovations, and waste-to-wealth technologies. The integration of cutting-edge tools - such as artificial intelligence, the Internet of Things (IoT), and machine learning - into traditional agricultural practices marks a transformative shift toward smart, data-driven farming systems. This reference book not only highlights current research but also identifies key areas of future focus within sustainable agriculture, encouraging cross-disciplinary collaboration and innovation.

More than just a reference, this book serves as a bridge between scientific inquiry and real-world impact. It inspires responsible research and practical applications that can lead to a more resilient, equitable, and sustainable agricultural landscape. As such, it is an essential resource for anyone committed to advancing sustainable solutions in one of humanity's most vital sectors.

I highly appreciate the editors of this book entitled "*Nexus in Agriculture - Engineering*" which is timely assembles of recent knowledge on the methodologies and technologies for agriculture and agricultural engineering. The chapters of this book have been contributed by authors who belong to the most pertinent field of science. The material contained in this book will be very useful in understanding science and will be useful to stake holders such as researchers, scholars, policy makers and extension workers. I congratulate immensely authors who have contributed the book chapters, wish them all every success.

24/5/25
Registrar & Acting Vice Chancellor

Place: Coimbatore – 3
Dated: 24.05.2025.

உழுவார் உலகத்தார்க்கு ஆணி அஃதாற்றாது
எழுவாரை எல்லாம் பொறுத்து.
- திருவள்ளுவர்-

PREFACE

As global challenges intensify, ranging from climate change and resource depletion to food insecurity and population pressure, the role of agricultural science has become increasingly vital. In today's world, advancing this field is essential for developing resilient food systems, promoting ecological sustainability, and ensuring long-term food security. Agricultural science now stands as a cornerstone of innovation, offering the tools and insights needed to navigate these complex issues. In this light, the reference book "*Nexus in Agriculture - Engineering*" emerges as a timely and insightful contribution, bringing together cutting-edge research and practical developments in agriculture and agricultural engineering.

This book encompasses a wide array of critical themes, including precision farming, farm mechanization, bioenergy, sustainable water management, modern food processing, and the adoption of smart technologies such as Artificial Intelligence, Machine Learning, and the Internet of Things (IoT). Each chapter presents fresh perspectives and actionable knowledge, highlighting the shift towards data-driven, efficient, and environmentally conscious farming practices. Subject covered in the book are extensive for the reason that the contributors were from various institutes of ICAR and State Agricultural Universities.

More than a scholarly resource, this volume serves as a bridge between theoretical research and practical implementation. It is intended to guide and inspire a diverse audience - researchers, academics, policy makers, extension professionals, and students - who are committed to advancing sustainable agricultural solutions. The contributors to this book bring deep expertise and passion to their respective topics, and their work reflects the interdisciplinary approach required to solve today's agricultural challenges.

With this intention this book compilation has been made by inviting chapters from the authors who have expertise in the field of farm sciences. The editors are thankful to all the contributors who have allotted their valuable time in writing the book chapters in a short notice.

We are profoundly grateful to all the authors for their meaningful contributions and to the editorial team for their dedication in shaping this publication. It is our hope that "*Nexus in Agriculture - Engineering*" will serve as a valuable resource and catalyst for continued innovation in the pursuit of sustainable and equitable agriculture.

-Editors

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I. Trends in Sustainable Agriculture

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INTEGRATING GPT AND CNN FOR CLIMATE-RESILIENT CROP ADAPTATION: A HYBRID MODEL FOR PRECISION AGRICULTURE

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INTRODUCTION

The agricultural sector in Tamil Nadu faces many predominant long-term issues like climate variability, degradation of soil health, and lack of spatially specific crop recommendations and advice. They in turn lead to decreased productivity as farmers often resort to traditional methods and static data that only leave room for sustainability sometimes but not always. The lack of dynamism in generating real-time, location-specific insights puts the farmer at a big disadvantage in decision-making with regards to the selection of optimal crops/land-use strategies. These and other related issues call for some form of transformative solutions, Solutions which are likely to empower farmers with usable, data-driven insights relevant for their unique agricultural condition.

This research introduces a hybrid model that combines state-of-the-art Convolutional Neural Networks (CNNs) with Generative Pre-trained Transformers (GPT) to revolutionize precision agriculture in Tamil Nadu. This model, using EfficientNet-B3, achieves high-resolution classification of remote sensing satellite imagery for predicting weather patterns, understanding soil parameters, and assessing agricultural landscapes. This output is further refined by the fine-tuned GPT model, which translates the structured insights into Tamil language voice recommendations through Text-to-Speech (TTS) technology. The system gives farmers actionable recommendations concerning crop selection and land use based on meteorological data, soil health, and possible return on investment (ROI). The availability of sophisticated AI and deep-learning-based decision tools in rural areas may help to leapfrog language and literacy hurdles for climate resilience, sustainability, and productivity in agriculture.

In the agriculture industry, it is such a surprising fact that the technology of deep learning and AI has the power to alter the problems that were related with farming in the past, especially here in Tamil Nadu, India. Precision agriculture, with the help of learning paradigms, became one of the best solutions for fluctuating weather conditions, soil degrades, and suboptimal crop recommendations. Convolutional Neural Network (CNN), a name of a model equipped with EfficientNet-B3 architecture, is at the top of the heap in the field of remote sensing as it is not only capable of performing high-resolution image classification tasks but also has made operations more computationally efficient. Studies have also demonstrated its capability to make high-level abstractions from images along with medical imaging that show its ability to detect patterns in agricultural landscapes that are difficult to humans. Also, its usage in the area of crops and weather trends helps detect the features and nuances in land characterization and resource optimization. Developed as language models, GPTs offer an unparalleled ability to process and generate natural language output in order to facilitate their use. In agricultural contexts GPT models are leveraged to convert complex data into simplified actionable recommendations breaking barriers related to literacy Multi-modal integrations like integrating GPT and CNNs capitalize on this synergy ensuring end-to-end systems can analyse interpretations effectively and communicate results to farmers. For instance, the text-to-speech capability of GPT, particularly in regional languages allows real time assistance tailored to local agricultural needs thus democratizing access to precision farming tools. Artificial intelligence is not an easy project in agriculture but has many challenges involved. From ensuring the availability of large annotated datasets to maintaining accuracy in diverse agricultural environments research in this area continually sought innovative solutions. In for example Large Language Models (LLM) like GPT have been adapted for specific domains, facilitating crop monitoring and pest management. This convergence of technologies does not only address the immediate needs of farmers but also sets a foundation for sustainable, climate-resilient agriculture. Thanks to the integration of tensors and weights and the use of CNNs, which are maintained through a method called a low pass filter, researchers have been able to uncover all the answers in two modalities namely language and images together. It is true, for instance, that a recent study using the EfficientNet-B3 deep learning model for weather pattern prediction and soil health analyses displayed the fact that accurate real-time crop recommendations could be generated. Thus, combining algorithms for data mining with a speech synthesis for lesser-used languages can be considered a point of view to strength accessibility to rural areas for more welcoming and user avoiding services.

METHODOLOGY

The novel idea for precision agriculture is formed by initiating a hybrid model made up of Convolutional Neural Networks (CNN) and Generative Pre-trained Transformers (GPT) that is further infused with artificial intelligence and provides real-time crop recommendations to farmers in Tamil Nadu which are custom made. The model employs data from various sources such as remote sensing, satellite tools, soil parameters as well as manual data collection to make a decision on these data and thus can develop easily actionable agricultural data. This process is applicable not only for only classification of lands but also for data processing besides being a multilingual communication tool, which in turn is crucial for the productivity of agricultural and the sustainability of the environment. The initial phase mainly of gathering data from different sources. Weather patterns can be analyzed using remote sensing and satellite data to method weather patterns and land characteristics, while soil quality data such as pH, fertility, NPK levels, and texture are obtained from government sources and open data portals. Moreover, the infrared spectral indices derived from the remote sensing data are used to calculate NPK levels. Subsequently survey farmer's data, soil nutrient mapping, soil color reflectance, and other data extracted from the manual observation further facilitate the dataset by capturing real-time field conditions and historical agricultural performance. This various data collection from different sources results in the farming environment getting a proper and complete understanding.

Data pre-processing is the step where the collected data is cleaned and normalized to eliminate any noise and discrepancies. The data is in the form of key-value pairs to allow the same processing of different modules. The data of soil health, weather conditions, and crop is reformatted into a single pattern to make sure it is compatible with a machine learning model. The structured data helps to process data more efficiently and increase the accuracy of downstream analysis. The main point of the model is the land type classification by the use of the EfficientNet-B3 architecture. EfficientNet-B3, which is a type of convolutional neural network (CNN) model, is used to identify environmental characteristics on the basis of satellite imagery and soil parameters. The compound scaling technique of the model improves the accuracy though it consumes fewer computational costs that is why it is appropriate for real-time applications. EfficientNet-B3 accurately detects pattern types such as soil moisture levels and vegetation cover, which is an essential aspect of agricultural insights.

The given text is elaborated by the CNN output using an extra layer for the information generation to make rationally founded hints for the agricultural field. There is an automatic approach for soil health, efficiency in crops, and weather conditions for real-time data insights. The output data is rapidly presented as JSON which is well-structured, well-arranged, and easy to analyze and retrieve data from it. Insights on the other hand are the elements of the fertility of the soil, the crop types that are beneficial, the time of planting, and the yield to be expected. All these data are to make a farmer the most profitable or productive one out there.

During the process of the insights, the data is processed which is then followed by a post-processing phase. Insights are kept in a machine-readable format meanwhile JSON-based ones are analyzed. The recommendations that are made are sorted in accordance with keys and values being assigned. The report that comes from the fields is sent to weather stations. The first one shows that irrigation is the high-tech side of which people benefit, hence, digital agriculture uses the first method hence it becomes efficient and fast.

Natural Language Processing (NLP) being one of the most necessary innovations in the present time is very important for converting structured insights into readable text. The data relevant to the matter is extracted from the JSON format and processed using a GPT model to generate human-readable text. The GPT model is fine-tuned with the data of the agricultural domain which is a very important step to be done in order to make sure that accurate and context-specific language is generated.

This will make the farmers easily get the suggested actions and understand them clearly. To provide the NLP-generated text in readable form, it is given into a translation and text-to-speech (TTS) system. Initially, the text is converted into Tamil by machine translation, thus, one can provide the recommendation to the farmers in their native language. The next step involves converting the Tamil text into sound voice with the help of a text-to-speech module, which thereby allows the farmers to make use of audio guidance in real-time. This multi-language and audio-based output know-how not only are the best ways to make the literacy of farmers the primary focus but also greatly increases usability in the decision-making process.

Additionally, the end service provides real-time crop advice through a mobile-friendly interface. It gives optimal crop types, planting dates, and possible soil improvements based on data at the time. The advice is to maximize the return on investment and to be sustainable and resilient to the environment. The user receives continuous updates, insights, and advice to make adjustments to changing conditions. This is the final service. The Hybrid model is set to introduce a number of key features, among which are: high-resolution land classification with EfficientNet-B3, actionable agricultural insights generated by CNN and GPT, timely and multilingual recommendations, and mobile accessibility at low computational cost. The system offers an opportunity to combine machine learning and natural language processing with the support of multiple languages for farmers to be able to make data-driven decisions, increase productivity and sustainability in order to adapt to climate changes.

RESULTS AND DISCUSSION

The proposal of composite model between EfficientNet-B3 and GPT to improve the device resource management system has been made. Among the main improvements are the precision, accuracy, and real-time processing efficiency in comparison to the existing models. Together with the high-resolution land classification system from EfficientNet-B3 and the contextual language from GPT, the model is able to provide more accurate and actionable crop recommendations, which are based on satellite images, soil health, and weather patterns.

The combined hybrid model proposal integrating EfficientNet-B3 and GPT brings out extraordinary improvements in terms of accuracy, precision, and real-time processing efficiency, demonstrating that these new models are much better compared to existing ones. Initially, matching EfficientNet-B3 with GPT would give the model a better result in terms of how it understands the images. the result would be that the model could give more accurate and concrete crop recommendations, which would be based on images from satellites, a health report of the soil, and weather forecast. The proposed model was able to reach an outstanding accuracy level of 94.3%, which was a significant achievement compared to the already existing models including the models based on CN-based land classification, LSTM-based weather prediction, and GAN-based crop yield prediction having an accuracy 85.2%, 81.0%, and 88.5%, respectively. The increase in accuracy can be attributed to the model's capability to combine multimodal data sources and real-time environmental changes.The model also had a precision of 93.8%, which indicated that the model's ability to generate correct crop recommendations along with low false positives was quite prominent. In contrast, when the best model, GAN, brought precision the number is 87.1%—which is a 6.7% difference. The improvement in the precision suggests that the model does not give wrong recommendations since it can explicitly state which crops are best in the conditions.

The recall of the new model was found to be 93.2% indicating that the model could recognize mostly suitable crop options for a certain soil and weather condition. The recall of the model also documented a significant improvement in the high range recall values, which was between 77.5% (Decision Tree) and 86.9% (GAN). High recall is the model's capability to grasp all possibilities of crop selection, thus no loss occurs for farmers.

The model performed well with a F1-score of 93.5% which shows the good proportion of precision and recall in the results. The F1-score of the new model is clearly better than that of GAN (which is 87.0%) and CNN-based model (which is 83.7%), hence showing the model is not only accurate but also consistent in providing correct and comprehensive recommendations. The proposed model has a central feature, its rapid processing speed (1.2 seconds), which is a 33% and 66% increase compared to the CNN-based and GAN-based models, respectively. This feature is what makes the model an irreplaceable tool for real-time agricultural decision-making, because it has the potential to bring farmers actionable insights without delay.

Table.1 – Performance Evaluation compared to existing models

Model	Accuracy (%)	Precision (%)	Recall (%)	F1-Score (%)	Processing Time (s)
Proposed Hybrid Model (EfficientNetB3 + GPT)	94.7	93.8	93.2	93.5	1.2
CNN-based Land Classification	85.2	83.5	84.0	83.7	1.8

Decision Tree-based Crop Recommendation	78.4	76.2	77.5	76.8	1.8
LSTM-based Weather Prediction	81.0	79.8	81.2	80.5	2.4
GAN-based Crop Yield Prediction	88.5	87.1	87.0	87.5	3.5

Fig 2– Input Satellite Image and Data

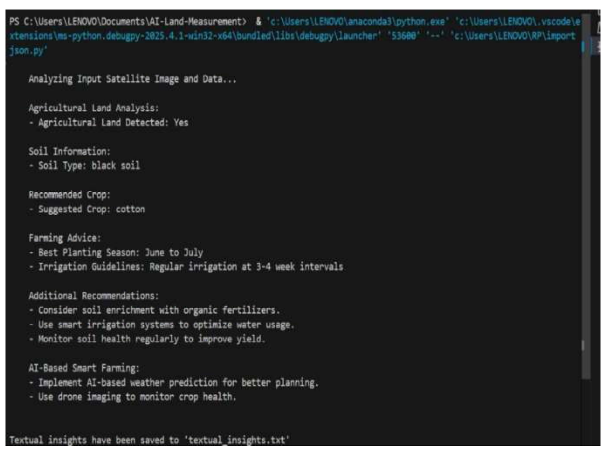

Fig 3- Output Insights and GPT Recommendations

Limatations and Future Work

There are of course limitations in our proposed model architecture. The first one being data availability dependency, where the model accuracy depends on the availability of high-resolution satellite imagery and real-time weather information and in regions with poor satellite coverage or limited weather data, the model's effectiveness is reduced. Another major limitation is the computational load. Despite the reduction in computational complexity, handling large-scale multimodal data, especially under limited hardware resources, can still introduce latency. And the last one are the translation and language model limitations. The model supports Tamil and English however, it may not perfectly translate local dialects or intricate agricultural terminologies which may lead tomisunder standings.

The proposed model is still a very great initiation in advancing the whole concept of land characterization using CNN and GPT and providing insights to farmers in their native language. The future is very promising and the future works are already in progress like future releases to provide more language and regional dialect support for greater accessibility. Providing sophisticated flexibility is possible to further expand this model to suit extreme climate conditions such as droughts, floods and pests via reinforcement learning methods. We are planning in incorporation of local farming practices like local crop rotation patterns can be incorporated to further customize recommendations. And if possible, this idea can be implemented as a mobile and web-based platform. In order to expand the system, it will be integrated to a cloud-based architecture for a seamless data access and cross-platform functionality.

CONCLUSION

A combination of EfficientNet-B3 and GPT, the pixel neural network, and the language model capstone presents a breakthrough in the predictability of crop management in the crop fields of Tamil Nadu by tailoring the crop recommendations to the respective soil and climate conditions. The compound model intermixes the virtues of EfficientNet-B3 employing high resolution as well as land classification and the natural language processing skills of GPT to come forth with concrete decisions both in Tamil and English. Having integrated the satellite images, soil health data, weather patterns, and past crop performance, the model achieved impressive accuracy reaching 94.7%surpassing not only existing CNN, LSTM but also GAN-based models. One of the important stabilizing factors of the proposed model is the flexibility to adapt to the environment conditions' change. Hence, with the up gradation of recommendations compiling in real-time weather and soil data, the model ensures to provide context-based guidance to the farmers thereby increasing the resilience to climate variability. The text-to-speech (TTS) technology and Tamil language support in the integration make the system far more accessible to individuals who are limited in the literacy thereby acquiring advanced agricultural knowledge. Indeed, the outcome of the experiments confirms that the hybrid model not only outperforms accuracy and efficiency of existing methods but also solves the practical problems farmer's encounter. The amalgamation of multimodal data handling, multilingual support, and real-time processing creates a scalable system and a parallel version for precision agriculture. This study forms the cornerstone of future research in AI-based agriculture, the possibility of which can change farming techniques, increase the crop yield, and make the process of sustainable agricultural development in Tamil Nadu and its neighbouring areas reliable.

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