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74th Annual Conference of Indian Society of Agricultural Statistics

on

Harnessing Statistics and Artificial Intelligence for Sustainable and Smart Agriculture

February 02-04, 2024

Organized by

Department of Agricultural Statistics
N.M. College of Agriculture
Navsari Agricultural University, Navsari, Gujarat

SOUVENIR

74th Annual Conference of Indian Society of Agricultural Statistics

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Harnessing Statistics and Artificial Intelligence for Sustainable and Smart Agriculture

February 02-04, 2024

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Organized by

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Navsari Agricultural University, Navsari, Gujarat

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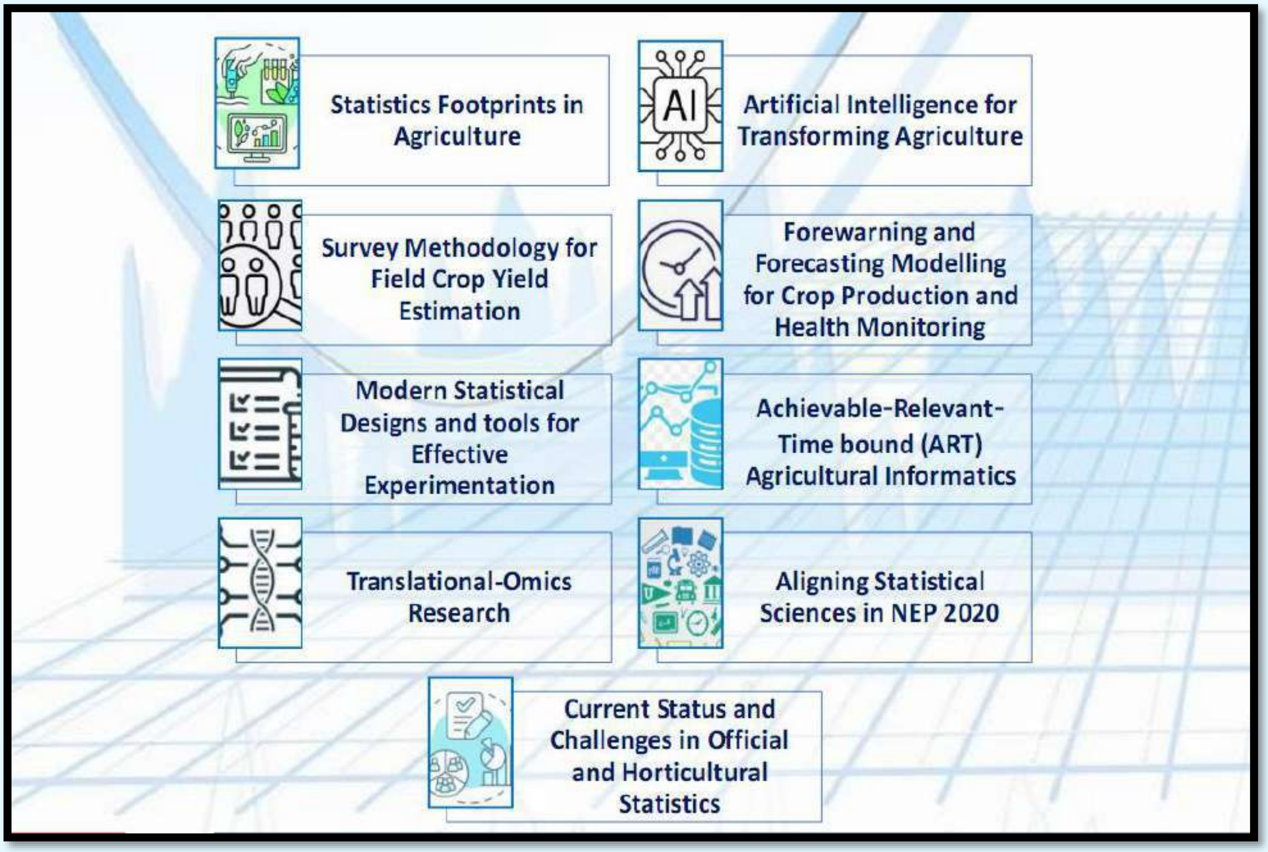
Statistics Footprints in Agriculture
Artificial Intelligence for Transforming Agriculture
AI
Survey Methodology for Field Crop Yield Estimation
Forewarning and Forecasting Modelling for Crop Production and Health Monitoring
Modern Statistical Designs and tools for Effective Experimentation
Achievable-Relevant-Time bound (ART) Agricultural Informatics
Translational-Omics Research
Aligning Statistical Sciences in NEP 2020
Current Status and Challenges in Official and Horticultural Statistics

डॉ. जी.पी. सामंता
सचिव एवं भारत के मुख्य सांख्यिकीविद्

DR. G.P. SAMANTA
Secretary & Chief Statistician of India

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MESSAGE

I am happy to learn that the Indian Society of Agricultural Statistics (ISAS) founded in 1947 with Late Dr. Rajendra Prasad as founder President has grown in strength over time and its now organizing its 74th Annual Conference on the theme **Harnessing Statistics and Artificial Intelligence for Sustainable and Smart Agriculture** at Department of Agricultural Statistics, N.M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat during February 02-04, 2024.

In India, we need the detailed agricultural statistics at the national, sub-national and farm levels for agricultural policy decision, placing agricultural development and estimates of the agricultural and national income. Agricultural Statistics together with judicious use of informatics provide the foundation for sound agricultural research and informed policy planning. Significant and original contributions have been made by Indian statisticians in the area of Design of Experiments, Sampling Techniques, Statistical Genetics, Modelling and Forecasting Techniques. Statistics have also been a data-driven science and more recently the statisticians have been handling the analysis of massive data sets with perfection using their statistical skills.

I am happy to share that India has been elected in the United Nations Statistical Commission (UNSC) as a member for a term of 4 years 2024-2027 after nearly two decades. In the present times and in the times to come, the importance of data cannot be overstated. Conference on the above theme is a timely step. Harnessing Statistics and Informatics along with Artificial Intelligence (AI) / Machine Learning (ML) tools and Big Data Analytics provide potential opportunities to increase productivity of different sectors of agricultural sciences while minimizing environmental impact. This can lead to new insights and innovations that further improve the sustainability and efficiency of smart agriculture.

I am sure that this Conference will provide a wider platform to bring together eminent scientists from different parts of the country and abroad to deliberate upon current challenges of research in agricultural statistics and informatics in view of the newer emerging technologies in agricultural research.

I wish the Conference a grand success.

G.P. Samanta

(G.P. SAMANTA)

NEW DELHI
24.01.2024

Trilochan Mohapatra

Chairperson
Protection of Plant Varieties and Farmers' Rights Authority
(A Statutory body created by an Act of Parliament)
Ministry of Agriculture and Farmers Welfare
Government of India

MESSAGE

It is heartening to note that Agricultural Statistics in the country stands on a sound footing. Recognizing the efforts of statisticians and the importance of statistics in agricultural research, the Indian Society of Agricultural Statistics (ISAS) was founded on January 03, 1947 with the then Agriculture Minister, Dr. Rajendra Prasad as its Founder President. Dr. Rajendra Prasad continued to preside over the activities of the Society for 16 years even after becoming the President of the Republic of India. The Society hosted the VIII International Conference on Agricultural Statistics VIII (ICAS VIII) in 2019 which was a grand success. More than 300 delegates from abroad participated in this event. Now, India has been elected to the United Nations Statistical Commission (UNSC) as a member for a term of 4 years 2024-2027. Keeping in view these developments, we should establish a Global Knowledge Hub on Agricultural Statistics, particularly for enhancing south-south co-operation under the aegis of the ISAS.

I am happy that the Society is organizing 74th Annual Conference on the theme **Harnessing Statistics and Artificial Intelligence for Sustainable and Smart Agriculture**. The theme chosen for the conference is timely and will encourage the use of Statistics and Data Science in furthering the cause of **Sustainable and Smart Agriculture**. I hope that the deliberations in this Conference would identify new areas of research in the discipline of Agricultural Statistics, Computer Applications and Bioinformatics with a view to transform Indian Agriculture.

I wish the Conference a great success.

(T. MOHAPATRA)

Dated: 25th January, 2024

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Navsari Agricultural University
Navsari, Gujarat

Dr. Z. P. Patel
Vice-Chancellor

MESSAGE

I am delighted to discover that the Indian Society of Agricultural Statistics, founded by Dr. Rajendra Prasad in 1947, is on the verge of achieving a significant milestone by organizing its 74th Annual Conference at Navsari Agricultural University, Navsari, Gujarat, scheduled during February 02-04, 2024. This accomplishment underscores the society's enduring commitment to advancement and growth throughout its journey.

Continuing its legacy of embracing innovation in statistical applications for agricultural advancement, the society has aptly themed the conference "Harnessing Statistics and Artificial Intelligence for Sustainable and Smart Agriculture." In the contemporary era, where data is often referred to as the "oil of the 21st century," this theme resonates deeply, acknowledging the vital role of statistics in comprehending our society, world, and universe. The integration of statistics and artificial intelligence (AI) for sustainable and smart agriculture is pivotal for optimizing resource utilization, improving efficiency, and ensuring environmental sustainability.

I am confident that the conference will foster a dynamic exchange of knowledge, views, and ideas in an open and constructive environment. Eminent researchers, academicians, statisticians, computer scientists, students, and other delegates will contribute to this vibrant discourse. My heartfelt congratulations to the organizers for choosing a pertinent theme that addresses current challenges and underscores the essential roles of applied and pure statisticians in upcoming critical scenarios.

I extend my best wishes for a successful and impactful event that contributes to advancing statistical applications in crucial areas. May the conference be a grand success, furthering the frontiers of knowledge and innovation in the field of agricultural statistics.

I wish the Conference a grand success.

Navsari

January 24, 2024

(Z. P. Patel)

भारतीय कृषि अनुसंधान परिषद
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Message

I am glad to learn that the Indian Society of Agricultural Statistics (ISAS) is organizing the74th Annual Conference on the theme **Harnessing Statistics and Artificial Intelligence for Sustainable and Smart Agriculture** at Department of Agricultural Statistics, N.M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat from 02 to 04 February 02-04, 2024. Emerging concept of Sustainable and Smart farming make agriculture more efficient and effective with the help of high precision algorithms. In this modern era of technology, Agriculture has moved past the small scale and labour intensive farming stage to a modernized and technologically advanced version. Data science and artificial intelligence help farmers to track their crops, animals and water usage besides making them aware about pests or diseases present in their fields. It also provides insights into historical data, including past land usage and hyper local weather insights.

I am sure that the Society would continue its efforts to promote research in Statistics, Data Science and Artificial Intelligence to help in improving the quality of agricultural research as well as the quality of life of farming community.

I convey my best wishes for the grand success of this prestigious National Conference.

(R. C. Agrawal)

25th January, 2024

Dr. Padam Singh
Executive President
Indian Society of Agricultural Statistics (ISAS)

Message

Indian Society of Agricultural Statistics (ISAS) is organizing its 74th Annual Conference at Department of Agricultural Statistics, N.M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India during February 02-04, 2024. The Conference has an important theme "**Harnessing Statistics and Artificial Intelligence for Sustainable and Smart Agriculture"** which is the need for the current era.

During the conference, the prestigious Dr. Rajendra Prasad Memorial Lecture will be delivered by Dr. T. Mohapatra, Chairman, PPVFRA and Former Secretary, DARE and Director General, ICAR. Dr. P.S. Pandey, Vice-Chancellor, RP CAU, Samastipur will deliver the Dr VG Panse Memorial lecture. Dr. M. S. Swaminathan Memorial Lecture will be delivered by Dr. Himanshu Pathak, Secretary, DARE and Director General, ICAR. Dr. Ramjibhai Patel Memorial Lecture will be delivered by Dr. NM Patel, Former Principal, B A Collge of Agriculture, AAU Anand.

There will be memorial sessions in the memory of Dr. C. R. Rao, Padma Vibhushan, Fellow of Royal Society of Statistics & Recipient of International Prize in Statistics and Dr. Prem Narain, Former Director IASRI and Executive President ISAS. Additionally, there will be centenary celebration in the memory of Dr. M. N. Das, Former Director IASRI and Honorary Secretary ISAS.
The Conference will feature many sessions on different sub-themes along with special Lectures/Invited Talks/Presentation of Contributed Research Papers etc.
The conference will be attended by above 100 participants across the globe.
Planners, policy makers and scientific community will be benefited by deliberations during the conference.
I wish every success for the conference.

Padam Singh

Dr. Padam Singh.

भा.कृ.अनु.प.- भारतीय कृषि सांख्यिकी अनुसंधान संस्थान
लाइब्रेरी एवेन्यू, पूसा, नई दिल्ली-110 012

ICAR-Indian Agricultural Statistics Research Institute
Library Avenue, Pusa, New Delhi-110 012

डॉ. राजेन्द्र प्रसाद
निदेशक
Dr. Rajender Parsad
Director

MESSAGE

It is my singular pleasure to see that the Indian Society of Agricultural Statistics is having its 74th Annual Conference at Department of Agricultural Statistics, N.M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat. This conference continues the series of annual conferences that have become a key meeting ground for the statistics and informatics community, bringing together academic experts, researchers, faculties, and students in the broad spectrum of areas that constitute statistics, agriculture and informatics. This year's theme **Harnessing Statistics and Artificial Intelligence for Sustainable and Smart Agriculture** resonates well with the positive, forward-looking vibe that accompanies the setting of a platform for research and academics in the multidisciplinary research in ever evolving and transforming agriculture with digital innovations.

Sustainable and Smart agriculture is a rapidly growing field that aims to increase productivity of different sectors of agricultural sciences while minimizing environmental impact. Harnessing Statistics and Informatics along with artificial intelligence (AI) tools is key to achieving this goal.

I am happy to know that India has been elected in the United Nations Statistical Commission (UNSC) as a member for a term of 4 years 2024-2027, a recognition to Indian Statistics fraternity.

This conference would provide a leading forum for sharing the latest ideas and research areas amongst scientists, faculties, students, researchers and academicians in the area of statistics and informatics from different parts of the country. Interactions and deliberations among them would lead to more collaborative, innovative and cohesive research in newer areas of Statistics and Informatics.

While the scientific programme promises to be an outstanding experience and delicious academic recipes, I hope that everyone will also enjoy all that the city of Srinagar has to offer in the days before or after the conference.

I wish the Conference a great success.

(Rajender Parsad)

Dated: January 29, 2024

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Navsari Agricultural University
Navsari, Gujarat

Dr. T. R. Ahlawat
Directorate of Research

I am pleased to learn about the upcoming 74th Annual Conference of the Indian Society of Agricultural Statistics, scheduled to take place at Navsari Agricultural University, Navsari, India, from February 2-4, 2024. The conference theme, "Harnessing Statistics and Artificial Intelligence for Sustainable and Smart Agriculture," aligns with the global buzz surrounding technological revolutions such as Data Analytics and Data Science.

The symbiotic relationship between Statistics and Agriculture has been pivotal in addressing various challenges and fostering mutual growth. The integration of statistics and artificial intelligence (AI) has emerged as a transformative force in agriculture and horticulture, facilitating sustainable and intelligent practices. In horticulture, this collaboration optimizes cultivation processes through precision farming, leveraging statistical analysis and AI algorithms to manage resources efficiently.

The conference theme and its diverse technical sessions are poised to address complex issues, offering solutions in the presence of experienced statisticians. It is noteworthy that India has been elected to the United Nations Statistical Commission (UNSC) for the term 2024-2027, underscoring the significance of this core subject across different domains.

I am confident that the conference will foster a dynamic exchange of knowledge, views, and ideas among a distinguished gathering of statisticians. My sincere congratulations to the organizers for selecting a theme that addresses current challenges and emphasizes the crucial roles of applied and pure statisticians in upcoming critical scenarios. I extend my best wishes for the grand success of the conference

I wish the Conference a grand success.

Navsari

January 24, 2024 **Dr. T. R. Ahlawat**

एस. के. भाणावत, आई. एस. एस.
उप महानिदेशक
S. K. BHANAWAT, ISS
Deputy Director General

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राष्ट्रीय सांख्यिकीय कार्यालय
क्षेत्र संकार्य प्रभाग
Government of India
M/o Statistics & Programme Implementation
National Statistical Office
Field Operations Division

सत्यमेव जयते

Message from DDG, NSSO(FOD), RO, Ahmedabad, Gujarat

I am happy to note that Indian Society of Agricultural Statistics (ISAS) is organizing its' 74th Annual Conference at Department of Agricultural Statistics, N.M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India jointly with National Sample Survey Office (NSSO), Gujarat during February 02-04, 2024. The Conference has an important theme "***Harnessing Statistics and Artificial Intelligence for Sustainable and Smart Agriculture***" which is the need of the current era.

NSSO plays a crucial role in collecting reliable and comprehensive data on various aspects of the Indian economy, including agriculture. By providing accurate and timely data, NSSO serves as an important resource for implementing data-driven approaches in agriculture. In the context of sustainable and smart agriculture, agriculture data forms the basis for developing robust AI models. These models leverage historical and real-time agricultural statistics to optimize resource allocation, enhance crop predictions, and enable precision farming practices. The integration of NSSO data with AI technologies empowers policymakers and farmers with actionable insights, fostering a more sustainable and efficient agricultural sector in the current scenario.

The Conference will feature many sessions on different sub-themes along with special Lectures/Invited Talks/Presentation on Contributed Research Papers etc. The conference will be attended by about 170 participants across the globe. Planners, policy makers and scientific community will be benefited by deliberations during the conference.

I anticipate that this conference will add a fresh perspective to the continuing applied and theoretical work across various domains, providing valuable insights that will be beneficial to the participants in numerous ways.

I wish every success for the conference.

29.1.2024
(S K Bhanawat)
Deputy Director General

NAVSARI AGRICULTURAL UNIVERSITY

Dr. N.M.Chauhan
Director of Extension Education

Directorate of Extension Education
Navsari Agricultural University
Eru Char Rasta, Navsari-396450
Phone : 02637-282026
E-mail : dee@nau.in, **Website** : www.nau.in

Dr. N. M. Chauhan
Director of Extension Education

Message

I am pleased to learn about the upcoming 74th Annual Conference of the Indian Society of Agricultural Statistics, scheduled to take place at Navsari Agricultural University, Navsari, India, from February 2-4, 2024. The conference theme, "Harnessing Statistics and Artificial Intelligence for Sustainable and Smart Agriculture," aligns with the global buzz surrounding technological revolutions such as Data Analytics and Data Science.

The combination of statistics and artificial intelligence (AI) has emerged as a game-changer in agriculture, particularly through extension activities carried out by grassroots workers of KVKs. This integration facilitates the effective dissemination of information, crucial for farmers' welfare. AI-driven data integration plays a pivotal role in empowering farmers with valuable insights, particularly influencing government policies aimed at agricultural development. The collaboration between statistics and AI enhances the efficiency and reach of extension services, benefiting farmers at various levels. In essence, AI's role in data integration is indispensable for driving informed decision-making and promoting sustainable agricultural practices.

I am certain that the conference will encourage a vibrant exchange of insights among esteemed statisticians. Congratulations to the organizers for choosing a theme that tackles present challenges and underscores the vital roles of statisticians in critical scenarios. Best wishes for the conference's success!

I wish the Conference a grand success.

(Dr. N. M. Chauhan)

Navsari Agricultural University
Navsari, Gujarat

Dr. R. M. Naik
Principal & Dean

Message

The 74th Annual Conference of the Indian Society of Agricultural Statistics (ISAS) is set to take place at the Department of Agricultural Statistics, N.M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India, from February 02-04, 2024. The conference will focus on the crucial theme of "***Harnessing Statistics and Artificial Intelligence for Sustainable and Smart Agriculture***," addressing the contemporary needs of the agricultural sector.

The conference program comprises varied sessions covering different sub-themes, including special lectures, invited talks, and presentations of research papers contributed by participants. With an anticipated attendance of over 200 participants worldwide, the conference strives to offer valuable insights and discussions beneficial to planners, policymakers, and the scientific community.

The close connection between Statistics and Agriculture has played a crucial role in overcoming challenges and promoting shared progress. The combination of statistics and artificial intelligence (AI) has become a powerful influence in agriculture, enabling sustainable and smart practices. In farming, this partnership enhances cultivation processes by using precision farming, which utilizes statistical analysis and AI algorithms to manage resources effectively.

The presence of a group of experienced statisticians will pave the way for ongoing research in the country, including Gujarat. Their expertise will also prove beneficial in resolving complexities arising from various datasets encountered in different research endeavours

My congratulations to the organizer and their team for successfully arranging a national-level seminar on a crucial and timely topic, despite having limited staff.

I extend my best wishes for the success of the conference.

Navsari

January 24, 2024

Principal & Dean

DEPARTMENT OF AGRICULTURAL STATISTICS
N. M. COLLEGE OF AGRICULTURE
NAVSARI AGRICULTURAL UNIVERSITY
NAVSARI - 396 450

Dated 29/01/2024

Dr. Alok Shrivastava
Professor and Head

MESSAGE

On behalf of the Department of Agricultural Statistics at N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India, I extend a warm welcome to you for the 74th Annual Conference of the Indian Society of Agricultural Statistics (ISAS, 2024) scheduled to take place from February 2nd to 4th, 2024. The conference theme is "Harnessing Statistics and Artificial Intelligence for Sustainable and Smart Agriculture."

The conference serves as an exceptional platform for the exchange of innovative ideas and technical expertise, fostering advancements in this continually evolving field. The program encompasses a memorial session dedicated to esteemed statisticians, featuring keynote addresses from prominent academicians, and paper presentations by scientists and research scholars.

The foundational elements of Data Science and Data Analytics are rooted in the collaboration of Statistics and Computer Science. In our current data-driven landscape, the significance of interdisciplinary studies and research in Statistics has never been more pronounced. The challenges posed by Artificial Intelligence (AI) emphasize the need for the development of advanced models and techniques. Attending and actively participating in conferences focused on Artificial Intelligence, Machine Learning, and Forecasting, as well as Translational-Omics Research, offers students and researchers a valuable opportunity to stay abreast of the latest advancements in these fields. Such conferences provide a platform for interaction and knowledge exchange with keynote speakers who are authorities in their respective areas of expertise.

I would like to thank the sponsors and other organizations that have made this conference possible. Without their support, this conference would not have been possible.

I want to express my sincere gratitude to the organizing committee, especially Dr. Yogesh A. Garde and Dr. Nitin Varshney from the Department of Agricultural Statistics at N. M. College of Agriculture and the local organizing team at Navsari Agricultural University, Navsari. I also extend my appreciation to the Indian Society of Agricultural Statistics for their dedicated efforts in making this conference a reality. I am confident that all participants will find the conference to be both rewarding and valuable. Furthermore, I would like to congratulate my colleagues, student representatives, and committee members for their relentless work in coordinating this event.

I wish the conference every success.

(Alok Shrivastava)

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Hon'ble Vice-Chancellor
Navsari Agricultural University, Navsari, Gujarat

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Dr. Alok Shrivastava
Professor & Head
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ABSTRACT

MS 1: Memorial Lecture

Status of Agricultural Statistics in the State Agricultural Universities of Gujarat

N. M. Patel
Former Principal, B A Collge of Agriculture AAU Anand

Statistics, in a broad sense, means to process the data and interpret them. Gujarat has firm base for data collection, especially for agricultural sector. Statistical workers associated with agricultural sector are dependent on the survey methodologies advocated by the IASRI and or ISI. Data so collected are being used by the government for policy purpose. Government use to depute employees for training purpose at IASRI, the main source of education in Agriculture and Animal Husbandry Statistics.

The students studying for B.Sc.(Agri) are imparted statistical knowledge (since start of college in 1947) in the subjects of Biometry and Field Plot Techniques. But for post - graduates there was no facilities for teaching and research in Agricultural Statistics up to 1962.

[***Bansilal Amratlal College of Agriculture, Anand, established in the year 1947 under the aegis of the then Institute of Agriculture, now Anand Agricultural University, is the only college for agricultural education, research and extension education in Gujarat, up to 1960***].

The subject Agricultural Statistics entered in the list of P.G degree courses in the year 1963 after return of Dr. Ramjibhai M. Patel from USA who was on deputation for Ph.D. program in Experimental Statistics.

Dr. Ramjibhai Madhavbhai Patel (Nov.,1,1930-Dec.,20,2022) was the first Gujarati Agril. Statistician, popularly known as Ram among his friends and co-workers. Ramjibhai was born in a middle class farming family of Zadeshwar village, Dist. Bharuch, Gujarat on Nov.,1,1930.

After his secondary education he joined science college for getting inter-science certificate which was a must for admission in the agriculture college at that time. He earned B.Sc.(Agri) Hons in 1951 from Bansilal Amratlal College of Agriculture(BACA), Anand, Gujarat. He continued to study in Plant Breeding to secure M.Sc.(Agri) under the supervision of Prof. P.L.Patel; completed master program in 1953. For this degree program he was awarded scholarship by the Instituted of Agriculture, Anand.

Institute was intended to train its own staff member in statistics to cater to the need of education as well as research. Rmajibhai M Patel was deputed for Senior Certificate in Agril. and Ani. Hus. Statistics at IASRI, New Delhi. He completed this course work in 1956 with gold medal. Under faculty improvement program of the institute, Ramjibhai Patel under took Ph.D. studies in Experimental Statistics at the Graduate faculty of North Carolina State College, Raleigh, USA. He was financially supported by the Rockfeller Foundation USA. Dr. Columbus Clark Cockerham was his major guide, Advisory committee consisted of well-known learned professors namely Dr. H. L. Lucas, Dr. D.D. Mason and Dr. D.P. Matzinger. After completing Ph.D. in 1962 he returned to India and joined Institute.

After graduation he joined as Agri Officer, Department of Agriculture, Saurashtra Government (1953-1954), after M.Sc. Agri Institute of Agriculture, Anand appointed him as Jr.Res.Asstt(1954-1956), Sr.Res.Asstt(1956-1958) and Sr.Statistical Asstt in 1958. All these positions were held at the Bidi Tobacco Research Station of the Institute.

Dr. Patel was appointed as Asstt.Prof. of Agril. Statistics at BACA in 1962(after Ph.D.). He formulated curriculum for M.Sc.(Agri) and Ph.D. degrees in Agril. Statistics in 1963 and thereby new department- Dept. of Agril. Statistics was started in BACA; he headed it. The pioneer department in the country registered students for M.Sc.(Agri) and M.Sc. degree in Agril. Statistics in 1963 and Ph.D. in 1970. The degree program is partly by course work and partly by research. Course contents are revised as and when required to raise the quality of output. He supervised 20 M.Sc.(Agri) and 8 Ph.D. Scholars. His contribution relates to statistical genetics, crop losses due to pests and drought, nonorthogonal analysis for animal science, non-parametric methods etc.

Department progressed in such a manner that it attained status of University Department. The first agricultural university named Gujarat Agricultural University (GAU), came into operation in the year 1972 with its head quarter at Sardar Krushinagar-Dantiwada. Institute of Agriculture, Anand with its all projects and assets was made consituent component (campus) of GAU. The other campuses were located at Junagadh and Navasari making total four campuses of GAU. Statistics was given due weightage like agronomy and other departments at all the campuses by raising set up parallel to Anand. These campuses were transformed into university level in 2004. Now Gujarat state has four agricultural universities- Sardar Krushinagar-Dantiwada Agril.Uni., Anand Agril.Uni., Junagadh Agril.Uni. and Navsari Agril.Uni. All SAUs of Gujarat are offering post graduate degrees in Agril. Statistics.

Department of Agril. Statistics has computing facilities, computer laboratories / class rooms and data processing laboratories. Department helps scientists and students in planning of experiments, data analysis and interpretation of results. Department also plays significant role in administration (colleges and university), scrutiny of applications for admission in college, students records etc.

Achievements (Anand)

So for 68 M.Sc. (Agri.)/M.Sc and 26 Ph.D. scholars have earned their degrees from the department. Department was strengthened by adding staff positions and computing unit. In 1980 Statistical cell was sanctioned by GAU (at all campuses with H.Q. at Anand) which provided manpower.

In 1987, computer centre was established which helped to expand laboratory, class rooms and office area for the department. The same unit was upgraded by internet connectivity in 1997. All the units, projects, laboratories, departments, farms and central library were interlinked with each other. Central library i.e. Dr. M. D. Patel library was equipped as e-library which serves the western zone of country.

It is directly linked with ICAR also. Softwares - SPSS, SPAR-1, SPAR-2, Windows start, Systat, R.Python and Dos based programs are available for data analysis.

A research project, Statistical evaluation of experimental variability for improving efficiency of field experimentation is functioning since 1992. This project has advocated several scientific recommendations-specifically for plot size, number replications and crop based yardstick for c.v.% of field experiments. A Research Compendium on this project is brought out as publication.

P.G. research so far carried out by the scholars is published in summary form, named Research Highlights 1947-2017 and Research Accomplishments 2018-2022.

Future Goals

Department of Agril. Statistics, AAU, Anand is working in developing yardstick of c.v.% for field experimentation on crops. This work is very specific to individual crop grown in Gujarat, hence could not be extrapolated for entire country/ globe. IASRI has collected huge experimental data generated by research stations of ICAR Institutes and SAUs of India. This large area information could be utilized to study the various aspects of variability including yardstick of c.v.% for field experiments which can form common base for accepting or rejecting experimental results.

Soil health card project has generated huge soil nutrient data, covering almost entire country. Area statistics tool may help to categorize land area into different classes like rich, moderate, poor etc. such classification of farming area will save valuable resources of farmers and extension agencies.

Government announces minimum support price (MSP) for different crops based on cost of cultivation data of crops. This project is in operation in India since 1970-1971. Input component-wise data of cost of cultivation of crops could be utilised to standardise each component. Like-wise input cost/price of each input is also available.

It is feasible to evolve a statistical method for estimating cost of cultivation of crops. This will let go the present practice of data collection. Here one has to combine both standardised inputs and price/cost of inputs. This is a big task but statistically possible.

Lot of work is being done on large scale survey through sampling methods. But meagre work is carried out on sample size and sampling methods for experimental plots. Scientists are selecting at random few plants for recording observations on plant variables. This common practice is not proper to apply to each new variety of crop, the scientist(s) release. This basic aspect of sampling needs to be repeated and or confirm for each new variety of crops. Department of Statistics of each SAU can take up this task to help scientists to increase precision of experimental results. This holds true for yield estimation of fruits and vegetable crops having multi-harvest nature.

Use of efficient forecasting technology for crop production and pests and diseases needs prime importance. Joint venture with ISRO in this regard may prove most useful to nation. AI needs to be applied to this area of statistical research.

Strengthening Department of Statistics of SAUs

Agricultural statistics system provides data on crop area and production, land use, land holdings, irrigation, Agricultural prices, farm labours, farm machinery, livestock, fisheries, forestry, inputs statistics etc. for policy purpose. This system operates under Ministry of Agriculture, Directorate of Economics and Statistics and National Sample Survey Organization (at state and national level). The modification, changes, improvement in working, development of methodology, communication of reliable data etc. in system were suggested by Technical Committee (1949), National Commission (1976), Evaluation Committee (1983) and Workshop on modernisation of the statistical system (1998). The recommendations made by these bodies are implemented as and when required. Unfortunately, no attempt is paid to enhance teaching and research capabilities of the Department of Statistics of SAUs of the country.

The existing set up remains busy in advisory services. At few Agricultural Universities research is carried out through P G students. The output is not even 5 percent of the need of the Agricultural statistics system. This major constraint can be overcome by providing additional manpower for teaching and research. ICAR and IASRI, the apex bodies can initiate development project to strengthen Agricultural Statistics in SAUs. This project may be similar to NARP phase 1.

Students registered for Ph.D. degree in Agricultural Statistics in SAUs be given sufficient knowledge in statistics including official statistics. IASRI(ICAR) can help in teaching some of the courses to these students who will get benefit of two institutes. Proper procedure can be worked out for this type of arrangement.

There are number of statistical problems to narrate but time is a limiting factor.

Thank you all for hearing me calmly.

MS 2: Memorial Session

Time–Scaled Self Exciting Point Process Models and its Applications

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Self-exciting point processes describe random sequences of events where the occurrence of an event increases the likelihood of subsequent events in nearby time and space. Models for self-exciting point processes have many important applications to diverse topics such as earthquake and crime forecasting, epidemiology, invasive species, and social networks. The Hawkes Self-exciting process (Hawkes, 1971) is an important temporal model having the conditional intensity function as

$$\lambda(t|H_t) = \mu(t) + \sum_{t_i<t} g(t - t_i)$$

where $\boldsymbol{\mu(t)}$ is the rate of background events at time t is modeled by the Poisson process and g(.) is the triggering function due to the rate at which an event at time $\boldsymbol{t_i}$ triggers additional events at time t which is often follows exponential distribution. $\boldsymbol{H_t}$ denote the history of the occurrence of the events. The use of conditional intensity or baseline intensity is very common in repairable system models and reliability growth studies as they are usually modeled using Non-homogeneous Poisson models.

As the occurrence of spatial events and failure mechanisms of repairable systems have many commonalities in time domain (calendar time, date, frequency of occurrence, number of failures, etc.), where, the occurrence of one event can trigger the likelihood of other occurrence in time and space. This motivated us to introduce time scales in Self-exciting process and study their spatio-temporal behavior of the occurrence process with an application on Nepal earthquake data.

Finite Field Arithmetic using R

A Dhandapani
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A finite Field, also known as the Galois Field, is a field with a finite number of elements. A finite field is a set with two binary operations defined on the set usually called addition and multiplication. The number of elements in the set is called order of the finite field. The operations satisfy the associativity and commutativity of both addition and multiplication under the set, existence of additive and multiplicative identity in the set, additive inverse and multiplicative inverse are suitably defined, and the distributive law is valid. It is easy to construct a finite field using integers mod p, where p is a prime number. It is also possible to construct a finite field with nonprime fields whenever the order of the field is a prime number.

Finite Fields are useful in various areas including cryptography, coding theory, error correction codes, etc. They are also widely used in combinatorics, particularly in the construction of incomplete block designs and mutually orthogonal Latin squares.

It is straightforward to define and use a finite field with prime order in any computer software because it involves only modulo arithmetic. However, for a finite field with prime power, the operations are not easily available. A finite field with powers of 2, such as GF(2^3), can be represented with bit strings, and bit-wise operators can be defined for carrying finite field arithmetic. However, this approach cannot be extended to arbitrary prime powers.

The finite field arithmetic for both prime and prime power orders, it is possible to generate elements, addition and multiplication operations using functions available in HadamardR. HadamardR is an R package developed for generating Hadamard Matrices. For prime orders, two functions, GFPrimeAdd and GFPrimeMult, generate the addition and multiplication tables for a given prime number. In the HadamardR package, the Minimum Functions of various prime powers are stored in internal data frames. Using these minimum functions, one can generate the elements of the finite field and using GFADD and GFMULT functions, additive and multiplicative tables can be generated. The outputs of the table are indices of the elements of the finite field.

To illustrate, the addition table of GF(3^2) can be obtained using the script

```
Library(HadamardR)
p<-3
r<-2
```

```
cardin=9
mf<-subset(HadamardR:::minimumfunction,HadamardR:::minimum
function$s== cardin)
MF<-mf$coeff
GFElem<-GFELEM(p=3,r=2,MF)
GfADD<-GFADD(GFElem,p,r)
#output is a matrix of indices of size 9 x 9; indices are position number of
GFElem.
```

Thus, using the elements, addition, and multiplication tables, it is possible to implement various construction methods that involve arithmetic operations using finite-field arithmetic for both prime and prime powers.

Reference:
HadamardR – R package https://cran.r-project.org/package=HadamardR

Leaping forward from Statistical Genetics to Modern Day Statistical and AI Applications in Genomics

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The world population is projected at around 9.1 billion with a demand of 3 billion tonnes of cereals, for both food and animal feed uses, and 470 million tonnes of meat by 2050 (https://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Global_Agriculture.pdf). Plant and animal resources play an important role to meet the demand of proteins by the burgeoning population. Livestock provides around 27.9 percent of proteins directly through provision of meat, milk, eggs and offal. Therefore, it is essential to improve the trait performance of plants and animals, inter alia, the selection of better performing plants and animals to achieve the set targets of agricultural production. Also, it is necessary to apply the interventions based on genetic engineering, biotechnology, genomics, statistics and computer applications for improving crop and livestock production. With the advent of next generation sequencing techniques, generation of whole genome sequencing data has become technically more feasible at a reduced cost.

The information on whole genome level high density markers can be utilized for planning crop and animal improvement programmes.

The main aim of any crop and animal improvement programme is to change the genetic endowment of individuals to improve the performance of economically important traits. Traditionally, selection was done based on phenotypic performance of individual trait or one trait at a time, known as tandem selection. Also, selection was made simultaneously for all characters independently, rejecting all individuals that fail to meet the minimum standard for any one trait (Independent Culling Levels). Subsequently, DNA markers were used to improve the rate of genetic gains of economically important traits in plants and animals. Later, marker assisted selection (MAS) has been adapted in the crop and dairy industry. However, adaption of MAS is slow due to several reasons like large number of loci affecting the traits with each locus capturing a limited proportion of total genetic variance. Hence, small gains were possible with the available limited number of markers. However, recent advances in the genome sequencing techniques made it possible to discover thousands of Single Nucleotide Polymorphism (SNPs) from dense SNP arrays that cover the whole genome and explain majority of genetic variations in important traits through an approach called genomic selection or whole-genome selection.

Genomic selection (GS) has recently revolutionized breeding in crop and animal improvement programs. It offers the breeders to reduce cost, decrease generation interval, increase the accuracy and intensity of selection, which in turn increase the rate of genetic progress for economically important traits. GS refers to the decision of selection based on genomic estimated breeding values (GEBV). GEBV using genome wide genetic markers had gained considerable appreciation in the recent past. The genomic breeding values are calculated using a prediction equation based on SNP effects derived from a subset of individuals in the population (a reference population) that have SNP genotypes and phenotypes for traits of interest. A variety of statistical methods have been proposed to estimate the total breeding value. It was divulged that genomic selection could lead to a doubling of the rate of genetic gain.

More recently, cognitive functions mimicked by machines, especially computer systems, through Artificial Intelligence (AI) have been applied extensively in plant and animal genomics. A galaxy of researchers in the field of Artificial Intelligence accepted the challenge to throw light on some of the dark patches of hidden complex trait phenomena in plants and animals. Even though several factors can be ascribed for bringing improvement in trait expression, only a few of them such as machine learning, deep learning and predictive analytics are discussed. These applications cover prediction of gene structure, discrimination of cRNAs from ncRNAs, and further classification of different types of ncRNAs, DNA barcode-based identification of microbial species, stress responsive ncRNA prediction. Thus, the present talk is devoted to the challenging journey made from Statistical Genetics to modern day applications of AI in genomics.

Harnessing Statistical tools for sustainable and climate smart agriculture

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Statistics having roots in probability help in decision making. Statistical tools have huge potential in policy formulation especially in agriculture. Agricultural statistics published as official statistics and primary data obtained from farmers / various stakeholders in agriculture on sample basis can offer more insights only when appropriate statistical tools are employed. Statistical tools help to generate knowledge from data. Two examples offering policy recommendations after employing apposite statistical tools are given below.

Untapped production and bridging yield gaps

Yield gaps in field crops are often assessed by comparing yields realized by farmers with simulation experiments' -based biological yield potentials or yields obtained in research stations or yields obtained by farmers in on farm trials. Farmers argue that it is difficult to attain these yields without regular technical support and monitoring by experts. If potential yield in a crop for a region is set such that it is attained by a large number of farmers in a region having similar resources and without regular support by experts then farmers can be easily convinced about the attainability of the potential yield. Raju et al. (2018) suggested an approach to identify the regions having untapped potential for enhancing maize yield in India. It consists in delineating homogenous production zones for a crop with respect to climate (Raju et al., 2013), soil, season and irrigation under the crop, considering district as a unit using multi-variate cluster analysis. Yields in a cluster of districts are compared and the highest yield among them is taken as potential yield. Untapped yield potential in the remaining districts is estimated as a lag from the potential yield. Yield efficiency of a district in a crop is estimated as a ratio of yield of the district and potential yield. Yield efficiency ranges from 0-1. Deviation of efficiency score from 1 gives untapped yield potential score. Yield efficiency of a crop less than 0.5 for a district indicates that it has potential for doubling of yield in the crop. It was further suggested to look at the crop management with regard to adoption of high yielding varieties and nutrient management practised in the district with potential yield and explore the possibility of its replication in the remaining districts of the cluster so as to bridge the yield gap.

Administrator of a district may like to know where does the district stands with respect to yield efficiency when all important crops are considered together. If all the important field crops are studied simultaneously one can explore the opportunity of replacing a crop having low yield efficiency with another crop having high yield efficiency besides options of suggesting better agronomic management. Keeping all these aspects in mind this study assessed crop-wise yield efficiency of all-important crops other than maize and overall yield efficiency (including maize) at district level. Crop-wise untapped production at country level was assessed by multiplying untapped yield with area under the crop and aggregating (Table 1). The results revealed that Indian agriculture had the potential to produce an additional quantity of 90 million tonnes (Mt) of food grains with the existing cultivated area of cereals and pulses in TE2010-11. Untapped production at country level divided by area under the crop led to untapped yield country level. The untapped yield was found unbridged even in TE 2020-21 in food grain crops viz., rice, wheat, maize, chick pea, pigeon pea, black gram and green gram.

It becomes incomplete if the outputs of the work do not provide guidance on bridging the yield gaps. A decision support system (DSS) has been developed which brings out unrealized yield potential for a selected district and crop. The DSS also identifies 3 model districts and displays data of crop management and adoption of technology in them. The DSS has been hosted on ICAR-CRIDA website at http://www.icar-crida.res.in:8129/. This study provides some inputs for formulation of policy for bridging the yield gaps existing in several districts which eventually help in addressing the threatening food security in India.

Table 1: Untapped yield in major crops in India

Crop	**Untapped production (MT)**	**Area in M ha TE2010-11 (A1)**	**Untapped Yield in TE2010-11**	**Yield in t/ha TE2010-11 (Y_1)**	**Potential yield in TE2010-11 (Y_p)**	**Yield in t/ha TE2020-21 (Y_2)**	**Untapped yield in TE2020-21 (Y_p-Y_2)**

Rice	35.66	43.44	0.58	2.18	2.76	2.69	0.07
Wheat	31.57	28.43	0.85	2.91	3.76	3.50	0.27
Sorghum	2.97	7.57	-0.35	0.92	0.58	0.98	-0.41
Pearl millet	5.61	9.09	0.15	0.95	1.10	1.34	-0.24
Maize	8.36	8.33	1.20	2.33	3.53	3.09	0.44
Finger millet	0.62	1.31	-0.29	1.56	1.26	1.63	-0.37
Barley	0.06	0.68	0.15	2.31	2.46	2.85	-0.39
Chickpea	3.02	8.42	0.40	0.90	1.30	1.13	0.18
Pigeonpea	0.93	3.74	0.35	0.68	1.03	0.84	0.19
Blackgram	0.44	2.96	0.36	0.47	0.83	0.52	0.32
Greengram	0.68	3.18	0.47	0.38	0.84	0.56	0.29
Lentil	0.17	1.48	0.20	0.66	0.85	0.93	-0.07
Groundnut	3.50	5.83	0.35	1.19	1.54	1.73	-0.19
Sesamum	0.28	1.94	0.01	0.36	0.37	0.45	-0.08
Rapeseed & Mustard	1.14	6.26	0.35	1.17	1.52	1.45	0.07
Sunflower	0.14	1.41	-0.48	0.63	0.15	0.92	-0.76
Soybean	4.46	9.61	0.16	1.13	1.29	1.02	0.26
Castor	0.11	0.83	0.46	1.42	1.88	1.75	0.14
Cotton	0.80	10.26	0.11	0.44	0.55	0.43	0.12
Sugarcane	59.17	4.49	19.42	68.25	87.67	81.39	6.29

Prioritization of Climate Adaptation in sorghum

Climate change impacts the agricultural system directly or indirectly through many factors such as drought, dry spells, unseasonal rainfall and temperature extremes. The identification of adaptation options which could effectively counter various climatic stresses and their prioritization is very crucial. Adaptation options for various climatic stresses in a crop can be identified by expert consultation and/or by employing systemic review of literature. While prioritizing the adaptation options, not only their suitability or effectiveness against the stress but also adaptation barriers, their scalability, environment and other co-benefits have to be considered. Further the climatic stresses may have different degree of impact on crops in different agro-ecological features including irrigation (Irrigated/ Rainfed), soil type (Black/ Red or any other) and season (Kharif/ Rabi). Hence, the prioritization of adaptation options for specific geographies enables us to formulate effective location specific management strategies.

A study has been undertaken to identify and prioritize potential adaptation options for various climatic stresses in sorghum crop. Drought (moderate and severe), dry spells (short and long), high temperature (moderately high and very high) and untimely rains (moderate and intense) are identified as major climatic stresses for sorghum. A comprehensive list of effective adaptation options was prepared through systemic review of literature using PRISMA guidelines. The adaptations options identified are Ridge & furrow, Broad bed & furrow, Stress tolerant varieties, Compartmental bunding, Intercropping, Green manuring, Supplementary Irrigation, Zero tillage, Mulching and Stress specific nutrient management.

A workshop was conducted with about 20 multi-disciplinary scientists to evaluate effectiveness of various adaptation options against important hazards, adaptation barriers and scaling out opportunities on a scale of 0-5 and associated weightage. A scores of 5 indicates more effectiveness and 1 indicates less effective. Adaptation barriers considered are requirement of specialized inputs/machinery, small sized holding, cost of implementation, requirement of more labor, requirement of knowledge and skill and requirement of community cooperation. Yield in normal conditions, potential of inputs saving, drudgery reduction on women and environmental and other co-benefits were considered as the scaling out opportunities. A composite index was developed for each adaptation option considering the weights and scores assigned by experts. More weightage (70%) has been given to suitability of adaptation options to various climatic hazards which was further divided and allotted for effectiveness against each of the stress. In the remaining thirty percent weight, 14% weight was assigned to different adaptation barriers and 16% weight to various scaling out opportunities. The adaptation options which have high composite index were prioritized as most suitable options.

Further the adaptation options were prioritized for combination of geographical features namely, hazards (drought, agroecology (Irrigated/ Rainfed), soil type (Black/ Red or any other) and season (Kharif/ Rabi). Supplementary Irrigation, stress tolerant varieties, mulching and early sowing are the most effectives adaptation option for most of the cases.

The adaptation options suitable for different stress conditions can be identified by running a decision tree model. Trees explain variation of a single response variable by repeatedly splitting the data into more homogeneous groups using combinations of explanatory variables. CART, a nonparametric machine learning model was employed for generating the tree. Gini index method was used for determining the optimal split of a parent node into two child nodes.

The dependent variable was adaptation option, while agroecology, soil type, season and effectiveness against stress are taken as independent variables. In order to avoid complexity, the different intensity of drought and dry spells were aggregated as moisture stress, moderately high and very high temperature were aggregated as high temperature, and moderate and intense untimely rains were aggregated as untimely rain. In order to avoid overfitting issue, the overgrown tree has to pruned to obtain optimal tree. Complexity parameters (Cp) which finds a trade-off point between size of the tree and cross validation error was used to prune the tree. The size of the tree correspond to optimal Cp value was considered as the optimal tree.

For illustration purpose, a CART tree which was trained to identify the adaptation options suitable for moisture stress is furnished as Fig 1. If the ecosystem is irrigated, then no adaptation required. If the ecosystem is either kharif or rabi rainfed then there are different adaptation options suitable for different moisture stress score level. If the moisture stress score is less than 2.3, no tillage is found to be the suitable option. Supplementary irrigation is the suitable option when the moisture stress score is greater than 4.6.

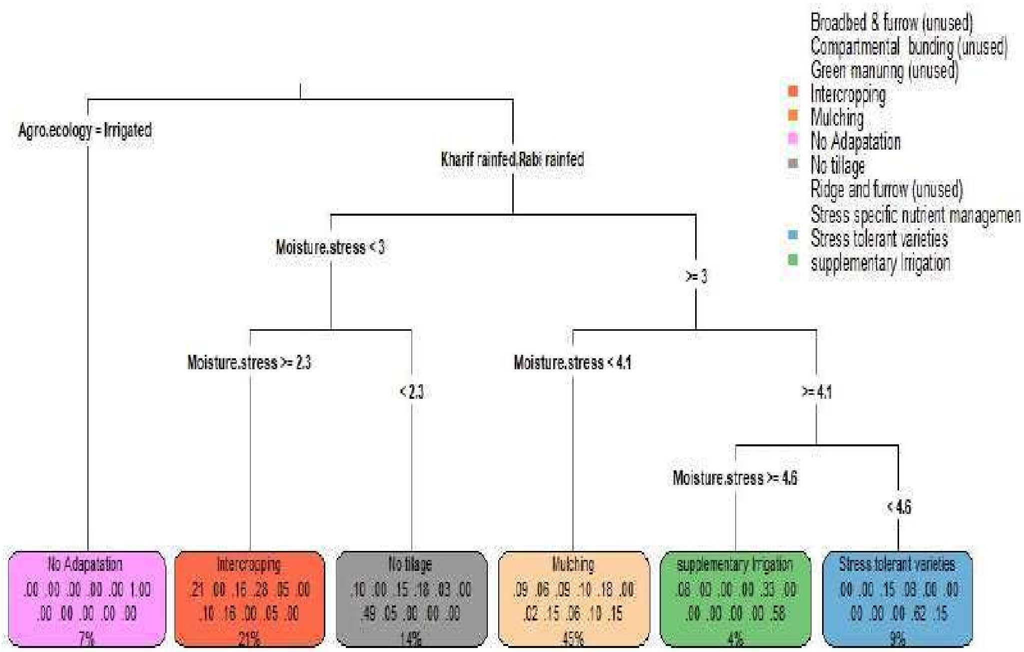

Fig 1: Decision Tree for adaption in sorghum

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Heritability Estimation with Correlated Error Structures

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The independence of observations is a crucial assumption in statistics and any deviation from this assumption has the potential to undermine the integrity of statistical analyses, casting doubt on the validity of conclusions drawn from the data. In the field of plant and animal breeding, the classical premise of independence between observations is violated. Primarily, the random component in the model the model, like errors, must adhere to specific assumptions, including normality and identical independent distribution, for accurate estimation of heritability. However, in many real-world situations, all of the assumptions are not fulfilled. This study focuses on the consideration of correlated error structures, particularly errors associated with estimating heritability in the half-sib and full-sib model. It is proposed that errors in the half-sib model follow distributions like the normal, beta, Cauchy, and t-distribution, and that sires and errors are correlated. AR(1) and AR(2) are the two error structures that have been investigated for the half-sib and full-sib models. A theoretical derivation of the Expected Mean Sum Square (EMS) in the context of the full-sib model has been obtained by taking the AR(1) structure into consideration. A numerical justification for the derived EMS within the AR(1) structure is given. Heritability is estimated using the resulting equations, and the predicted mean squares error (MSE) is obtained by integrating the AR(1) error structures into the model. Correlated errors are found to have a major effect on heritability estimation. It is possible to use different correlation patterns, like AR(1) and AR(2), to change MSE values and heritability estimates. For various scenarios, different combinations are suggested to achieve better results.

Keywords: *AR(1), AR(2), Correlated Error, Full-sib Model, Half-sib Model, Heritability*

Statistical Elegance in Genomic Selection Strategies

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Genomic selection represents an advanced version of Marker Assisted Selection, a breeding strategy where markers from the entire genome are employed to estimate the Genomic Estimated Breeding Value (GEBV). The calculation of GEBVs for individuals with only genotypic data relies on a model trained using data from individuals with both phenotypic and genotypic information. However, challenges such as high dimensionality, multicollinearity among markers, and the large p and small n problem (few individuals and numerous markers) pose significant hurdles in accurately estimating GEBVs. To address these challenges, various methods are employed, and this talk focuses on shedding light on the most commonly used approaches for GEBV estimation. Additionally, it explores the inherent challenges associated with these methods and proposes solutions by introducing extensions of existing techniques. Specifically, it discusses the applications of Ridge Regression and Genomic Best Linear Unbiased Prediction (GBLUP), along with innovative methodologies like Bayesian Alphabet and Least Absolute Shrinkage and Selection Operator (LASSO). These extensions aim to enhance the robustness and accuracy of GEBV estimation, overcoming the limitations posed by the unique characteristics of genomic data in breeding programs.

Keywords: *Genomic Associated Breeding Values, Statistical Models, Genomic Best Linear Unbiased Prediction (GBLUP), Bayesian Methods, Least Absolute Shrinkage and Selection Operator (LASSO)*

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MS 3: Centenary Celebrations

Life and Achievements of Late Professor M.N. Das

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The life sketch and professional profile of Late Professor M.N. Das will be presented. His path breaking contributions to different areas of Statistics, notably in Design and Analysis of Experiments, Theory of Survey Sampling and Statistical Inference. Some the following notable contributions Reinforced incomplete block designs, Circular designs, Intuitive method of construction of confounded designs for symmetrical factorials using the concept of identity matrix, Developing a somewhat unified method of constructing confounded designs for asymmetrical factorial experiments, Incomplete block designs for biological assays, Incomplete block designs for diallel crosses, Designing experiments with mixtures, Group testing designs, Analysis of covariance in two-way classification with disproportionate cell frequencies, Construction of second and third order rotatable response surface designs via balanced incomplete block designs, Second order response surface designs with equispaced doses, Efficiency balanced and Generalized efficiency balanced designs, Vedic Mathematics, Financial Statistics, etc. will be discussed.

Some Developments in Response Surface Methodology

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Response Surface Methodology (RSM) has the potential application where numerous input variables may impact a given performance metric or quality attribute of the final product or process and aids in the experimenter's pursuit of the best response. Agriculture, post-harvest research and industrial experiments are just a few of the research areas where RSM is applied. In Response Surface Methodology (RSM), it is assumed that the observations are independent and there is no effect of neighbouring units. But when the units are placed linearly with no gaps, the experimental units may experience overlap effects from the treatment combinations applied in adjacent units/ plots. Hence, it is important to include the overlap effects in the model to have the proper specification. Response surface models with overlap effects from immediate left and right neighbouring units have been studied and the conditions for the estimation and rotatability of these models have been obtained along with the variance of estimated response. Method of constructing designs for fitting response surfaces of various orders in the presence of overlap effects has been developed. The response surface analysis, incorporating the overlap effects from adjacent units, has also been illustrated and the overlap coefficient from neighbours is estimated such that the residual sum of squares is minimum. The results have shown substantial reduction in residual sum of squares and increase in precision of estimates of the parameters of the model. An R package rsdNE has been developed to generate some series of response surface designs with neighbor effects. Besides this, series of designs for fitting response surfaces for asymmetric factors under second and third order conventional response surface model setups have also been developed along with the designs for sequential experimentation. In order to generate the series of asymmetric third order rotatable designs, the R package MixedLevelRSDs has been developed and available for users.

TS 1: Statistics Foot Prints in Agriculture

INVITED TALK

Footprints of Statistics in Agrometeorology

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The beginnings of meteorology in the world can be traced back to India around 3000 B.C. era. Upanishadas, contain serious discussion about the processes of cloud formation and rain and the seasonal cycles caused by the movement of earth round the sun. Varahamihira's classical work, the Brihatsamhita, written around 500 A.D., provides a clear evidence that a deep knowledge of atmospheric processes existed even in those times. It was understood that rains come from the sun (Adityat Jayate Vrishti) and that good rainfall in the rainy season was the key to bountiful agriculture and food for the people. Kautilya's Arthashastra contains records of scientific measurements of rainfall and its application to the country's revenue and relief work. Kalidasa in his epic, 'Meghdoot', written around the seventh century, even mentions the date of onset of the monsoon over central India and traces the path of the monsoon clouds.

The Greek philosopher Aristotle wrote Meteorology, a work which represents the sum of knowledge of the time about earth sciences, including weather and climate. It is the first known work that attempts to treat a broad range of meteorological topics (Aristotle, 2004) For the first time, precipitation and the clouds from which precipitation falls are called meteors, which originate from the Greek word meteoros, meaning 'high in the sky'. From that word comes the modern term meteorology, the study of clouds and weather.

Meteorology, as we perceive it now, may be said to have had its firm scientific foundation in the 17th century after the invention of the thermometer by Daniel Gabriel Fahrenheit (Grigull, 1966) and the barometer by Evangelista Torricelli (Jacobson, 2005) and the formulation of laws governing the behaviour of atmospheric gases. It was in 1686 that Edmund Halley, a British scientist, published his treatise on the Indian summer monsoon, which he attributed to a seasonal reversal of winds due to the differential heating of the Asian land mass and the Indian Ocean (Cook, 1998).

The Statistics methods are presented as a science devoted to the proper analysis and interpretation of experimental data. Their methods are useful to elucidate valuable information from experiments, but also, these methods are often used to design the best experiments according to a specific objective.

The importance of statistical modeling and forecasting of time series data, etc., cannot be overemphasized. The benefits range from easy interpretability arising from visualization of results to the removal of the mysticism factor for the layman. The word 'forecasting' has to do with predicting the future based on data from the past and present. This is regularly done by the analysis of trends. A routine example might be the estimation of temperature trends for some specified future date. Compared to forecasting, prediction can be seen as a term which is more general.

Forecasting methods have been applied in different areas ranging from climatology, finance, foreign exchange, etc. This has been applied in different regions of the world for better prediction and simulation. The key distinction in Information and Communication Technology (ICT) is the fact that with this technology, we can make predictions and simulations from previously obtained data. This is true and can be applied for every area while paying attention to the rules that govern them.

It is important to note that the predictability of the atmosphere is not perfect, this brings into context the fact that although statistical methods are necessary, results obtained are not totally accurate which is why room for errors (uncertainties) are given, albeit, a trend can be observed (Daniel, 1995). Statistical methods have been applied in the study of different regions for example, Daniel S. Wilks in (Daniel, 1995) buttressed on the use of these methods on the analyses of different regions that do not necessarily have the same climatic condition. This brings into context the fact that laws are true irrespective of the region, i.e. neglecting all other factors that have little contribution to weather, the same methods can be applied in different regions to yield accurate results.

Analysis of trends can be useful in depicting and predicting the changing patterns and erraticism of some climatic parameters. This analysis gives a proper knowledge about the changing conditions of the climate and its effects, by the evaluation of meteorological parameters.

A data scientist using any tool or software for modelling and forecasting is particularly interested in the progression of these parameters (meteorological) as a function of time(t) f(t). The designers of navigation or monitoring systems cannot trivialize the importance of forecasting as this is a very important part of their system. The spatial and temporal changes of atmospheric parameters call for the adoption of this analysis to discern the effects of some meteorological parameters on other variables.

The applicability of forecasting cannot be underestimated because this is great information for people that depend on weather conditions like farmers, surfers, and event planners, etc. The accurate prediction of atmospheric parameters can go a long way in positively affecting the financials of the informed, as money can be saved by avoiding unnecessary cost during trying times (Datta et al., 2020). Natural disasters like Tsunami can be predicted with the correlation of meteorological parameters, harnessing information as explained previously and then incorporating this information through machine learning into the design of forecasting systems.

Statistics in Agrometeorology has played a significant role in quantifying relationships between weather and plants. The understanding of relationship between weather and crops/plants helps to take decision on sowing, phenological prediction, irrigation, fertilization, harvest predictions, yield prediction etc. The predictions are often linked with the supply and demand of agricultural commodities thereby helping farmers to take decisions when to sale and where to sale and which crop to grow and which crop to drop from rotation. This also helps policy makers to take decisions on import and export of agricultural commodities. The science of predictability in plant diseases and agricultural insects is becoming very popular in management of diseases and insects and reducing the crop losses. The comprehensive statistical analysis among soil, plant and atmosphere has culminated into development of crop simulation models. Crop simulation model acts as decision support system, which is being used by variety of users ranging from scientists, farmers, policy makers, market players and many more.

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Statistical and nearly statistical forays in the complex study of natural resources like fishes- An impression that thumbs through the steps of induction

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Statistics as it has been professed in the current phase has attained the status of what mathematics used to be a century ago. What all considered to be an applied version of the deductive concept leading to its inductive offshoot has now gone more basic and probably less deductive. In the Springer series of breakthroughs in statistics, Brad Efron's bootstrap occupied the last and thus the latest chapter till not long ago. With Cramer-Rao inequality and Rao-Blackwell theorem being labelled part of the pantheon of Puritan statistics and the inequalities between R.A. Fisher and Karl Pearson relegated to an epic era of yore, this powerful analytical warhorse has taken a different shape and thus relevance. Thus, to follow the trail of evolution and transformation of statistics in toto, one needs to wear many hats- theoretician, professional and practitioner.

Further, when the aspect of statistical applications in various fields of agriculture is to be evaluated, the complexity attains astronomical proportions. With agriculture being a cloud of concepts and scientific props embellished with pure non-scientific skill-based conjectural developments, the application of an applied domain on this highly amoebic field has its own trajectory of revelations and relevance. With crop-related facets of agriculture turning towards more and more micromanagement, the factors and parameters proliferate and thus the related metrics too. Gone are the days when one used to have a thumb rule relating the size of the sample and the number of variables. It isn't surprising to find commonplace tools and packages that deal with extremely rectangular data like genomic datasets. As it used to be once in vogue, Bonferroni correction, indicative of over-analysis of sampled information, the present set of tools and tricks create a new subworld of datasets to model options thereby making "over analysis" overtly simple. Options like ensemble modelling sound the grand arrival of statistical concepts getting an unexpectedly unique makeover, wherein both frequentist and Bayesian schools are left with a perpetual lurch. Just like the way the resampling concept revolutionised the population sample relationship these baskets of modelling options make the analytics involving otherwise challenging aspects of quantitative inference of vexed agricultural processes to be handled with a lot more computational audacity.

Even under the broader umbrella of agriculture a couple of subdomains like fisheries have a far more "sublimation" of concept-approach-inference routine being experienced. Quantitative analytics in fisheries science has always been vexed in handling the frontier cases of challenge-filled datasets. From being extremely unbalanced and lesser core being explicable, the fishery information right from the growth models to the stock-recruitment relationship has all the stuff that would challenge both the planning and understanding of swinging betting local and universal optima. Thus, the nonlinearity which has been the hallmark of quantitative fish modelling assignments has been both a harbinger of innovation of newer and evolutionary procedures as well as the Waterloo of the most decorated of analytical tools.

Carefully nurtured a century ago the concepts and tools in fishery data analytics, there was always a legal room for subjectivity. The more efforts were made to reduce the subjectivity, the more the expansion of the inferential band thereby leading to many goalpost-shifting situations. Even the flurry of solutions listed as the pride of modern data science had to take a back seat when it comes to handling fishery data. The oft-recommended AI and ML tools when applied in the commonest of fishery challenges like taxonomical identification and quantification perform precariously on the fitness metrics. Even when one thinks of the geotagging of the fishery data, it gets a minimum three-dimensional one with the depth being as crucial as that of the meridian and latitudinal tags. As a natural resource, fish is quite different from the rest of the resources of agriculture, in the sense that it gives an apparent mirage of being inexhaustible, yet recording sudden collapses. This kind of trend analysis gets more laboured when juxtaposed with the time series of climate change factors. Considering marine fisheries the intermingling of dynamics of oceanographic, climatic and biological factors makes the process of fishery modelling never an oligo-directional approach, let alone being unidirectional. The health of fish stocks can be healthy or unsustainable at the same time just by changing the angles of viewing them. With the kind of interlinking that is palpable under the thick sheet of water fishes do defy many common logical points of start and thereby make even the most “eventful” of algorithms like simulated annealing or genetic algorithm to lose teeth.

It can be safely presumed that just like the potential of Exclusive Economic Zone (EEZ) increases with each revalidation due to the technology creep, the statistical or near statistical tools as applied in this field reinvent and expand themselves only to find that there is a substantial chunk of their part remaining to be unravelled.

Meta-Analysis-An Important Statistical Methodology for Estimating Pooled Prevalence of Animal Diseases

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Meta-analysis is indeed a valuable statistical methodology widely used in veterinary epidemiology and public health research for estimating the pooled prevalence of important animal diseases. It involves the systematic review and synthesis of data from multiple individual studies to provide a more accurate and robust estimate of the overall prevalence of the disease.

Following steps are used in meta-analysis for estimating the pooled prevalence of animal diseases.

1. **Literature Review**: Identify and collect relevant studies that have investigated the prevalence of the target animal disease. This involves a comprehensive search of databases, journals, and other sources.
2. **Study Selection**: Apply predefined inclusion and exclusion criteria to select studies that meet the specific requirements for the meta-analysis. These criteria could include study design, sample size, geographic location, and diagnostic methods.
3. **Data Extraction**: Extract relevant information from each selected study, including study characteristics, sample size, prevalence estimates, and any other pertinent data.
4. **Quality Assessment**: Evaluate the quality of each included study to assess the risk of bias. This step helps ensure that high-quality studies contribute more to the overall analysis.
5. **Statistical Analysis**: Conduct statistical analyses to estimate the pooled prevalence of the animal disease. This typically involves using appropriate models, such as random-effects or fixed-effects models, depending on the heterogeneity among the included studies.
6. **Publication Bias Assessment**: Evaluate the potential for publication bias, which occurs when studies with statistically significant results are more likely to be published. Funnel plots and statistical tests can be used to assess and correct for publication bias.

7. **Subgroup Analysis and Meta-Regression**: Explore sources of heterogeneity by conducting subgroup analyses or meta-regression. This helps identify factors that may influence the variability in prevalence estimates across studies.
8. **Sensitivity Analysis**: Perform sensitivity analyses to assess the robustness of the results by excluding studies with certain characteristics or assessing the impact of different methodological choices.

By combining data from multiple studies, meta-analysis provides a more precise estimate of the overall prevalence of animal diseases, increases statistical power, and allows for the identification of potential sources of variation. It is an important tool in evidence-based veterinary medicine and can inform public health interventions and policies aimed at controlling and preventing the spread of animal diseases.

On Some Improved Imputation Methods Under MCAR Approach

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Missing data is an inevitable phenomenon in most of the sample surveys and when it is not handled cautiously at beginning of the study, outcomes may result to substantial biases in the survey estimates. Retaining such evidences into cognizance, this paper offers few possible improved imputation methods to figure out the problem of missing data at the starting of the study and proffers computation procedure of the population mean using simple random sampling. The characteristics of the offered imputation methods are ascertained till first order approximation pursued by a computational study carried out using several existent and hypothetical data sets. The findings are turned out rather promising showing dominance over the existing imputation methods.

FinTech Footprints: Reshaping Agriculture through Digital Finance

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Fintech is reshaping the agricultural ecosystem by technology driven innovation. Digital platforms are offering farmers with technologies that streamline financial operations, bridge loan access, and improve overall efficiency, from villages to large fields. The convergence of fintech and agriculture is about more than just financial transactions; it is about changing the way farmers approach their livelihoods. According to the UN, the world's population is on track to reach 9.7 billion by 2050, requiring a

corresponding 70% increase in calories available for consumption. By 2030, it predicts we will fall 40% short of meeting global water supply needs, and rising energy, labour, and nutrient costs are already pressuring profit margins. Agricultural development is key to fighting poverty around the world. India exported $38.54 billion in 2019 and 70% of its rural households depend on agriculture. Fintechs are at the heart of this revolution and it's their services and products that will connect farmers with finance and enhance the power of financial inclusion. According to recent research, if connectivity is implemented successfully in agriculture, the industry could add $500 billion in value to the global gross domestic product by 2030. Farmers are leveraging the power of fintech to alter the way they handle finances, access credit, and optimize operations as demand on the global food supply chain grows and sustainability becomes more important.

"FinTech Footprints" will showcase how data-driven insights derived from FinTech solutions empower farmers to make informed decisions, optimize resource usage, and enhance productivity sustainably. The talk will spotlight cutting-edge technologies and platforms facilitating smart investments and funding in agriculture, from crowdfunding initiatives to peer-to-peer lending.

Analysis of Covariance as a better alternative to randomized block design

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Often the experimenter in agriculture uses a randomized block design or any other design involving it, such as split plot design with the main plot in randomized block design. As per the theoretical necessity, the blocks should be taken perpendicular to the fertility gradient of the field, where the experiment is to be laid out. However, the experience tells that, hardly any experimenter takes note of this necessity, because it involves the soil testing at different locations of the field before carrying out the experiment.

Further, even if the experimenter carries out the soil analysis and determines the fertility gradient, most often it is not a straight line along a side of the field, so that the blocks may be taken perpendicular to it. Generally, the fertility gradient is zig-zag over the entire field. So, the question arises whether the block being taken for the experiment is valid as per the required theory? And, so that raises a question on the validity of the design undertaken.

Moreover, many a times the experimenter finds during analysis of variance that the block source of variation is not significant, still he/she goes ahead with further analyses, which is wrong, because that means that the blocks are not effective and hence are homogeneous with respect to each other. And then this means statistically that the completely randomized design should have been taken instead of randomized block design. However, a soil scientist may still say that the field is not homogeneous from fertility point of view.

So, to handle all these complexities, a new idea has has proposed as a thesis study for a student of Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh under the guidance of the author. The thesis topic is under process of approval by the University.

The basic idea of a block design is to remove the heterogeneous effect of the fertility already existing in field before layout of the treatments and ensuing measurements of various variables of the experiment, because otherwise the treatments from plot to plot would not be comparable. This study proposes to measure the N, P, K of all the plots of the experimental field before laying out the treatments into the plots. And then to carry out a typical analysis of covariance and shall be subsequently compared with the proper randomized block design to assess its efficacy.

ABSTRACT

Pattern and Determinants of Agriculture Household Income in India

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Abstract

The paper deals with the identification of determinants of crop income of agricultural households using the unit level data generated from Situation Assessment Survey (2018-19) of NSSO. NSS Survey has collected vast data starting from demography and education to land and its operations, diversification of crops harvested, production, sale and marketing, inputs and other expanses, outstanding loans, awareness of and access to technical advice and access to Govt facilities. The paper discusses the casual relationship with and impact of these variables on the crop income. It also identifies optimum combination of variables which models the relationship between crop incomes explaining large portion of variability in the crop income. Correlation and Step Wise Regression using multiplier as weights are used to determine the linear association and selection of appropriate set of variables within the Survey.

Pattern of the Determinants for five categories of land holding size, marginal, small, semi-medium, medium, and large and for a couple of States to model the

variability amongst the agriculture households has also been analysed. For different size class of households, and for different States, different set of optimum determinant variables have been found, nevertheless as measured by adjusted R^2 the multiple correlation coefficient, not more than 31.3% variability in the crop income could be explained by the variables at all India level. However, for sizeable number of States, the determinant variables could explain for more than 50% variability.
Keywords: *Agricultural Households, Survey Sampling Design Multiplier, Correlation and Regression*

Assessment of Genotype x Environment Interaction in Field Pea Genotypes: A Comparative Study of Parametric and Non-Parametric Methods

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Abstract
Genotypes x environment interaction continues to be a challenging issue among plant breeders, geneticists and production agronomists who conduct crop trials across diverse environments. Different approaches have been used to distinguish genotypes for their behaviour in different environmental conditions. There are various numerical and graphically stability methods to analyse G x E interaction and determine most stable genotype under varying environmental conditions. The numerical approaches which used in stability analysis are known as parametric and nonparametric methods. Though large numbers of stability measures (parametric and non-parametric) are available in literature, the problem of plant breeder has been to decide which of the stability measure is to be chosen for the purpose of selecting stable genotypes? The objective of the present paper is to analyse genotype × environment (G×E) interaction of 15 Indian field pea genotypes in 3 years and compare the parametric and non- parametric methods of stability. We analysed stability by different methods such as Eberhart and Russell, Superiority index, Shukla's stability, Wricke's ecovalence, etc. Most stable genotypes according to the parametric and non-parametric methods were G2 (PRAKASH), G8 (HFP 8712) and G10 (HFP 529).
Keywords: *Parametric method, Non-Parametric method, Genotype x Environment Interaction.*

Improved Estimates of Agriculture Household Income at Sub State Level in India

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Abstract

The paper fills in the gaps of granular data on income of agriculture households meant for capturing the disparity in income, across districts in India. NSSO has recently conducted Situation Assessment Survey of Agriculture Households in India with reference period of July 2018 to June 2019. Direct survey estimates have less precision owing to small sample size. The paper uses small area linear mixed models to provide reliable estimates of agriculture household income by strengthening the NSSO direct survey estimates with supplementary data on population, livestock, and agriculture yield. The results show significant improvement in district estimates. Optimum combination of supplementary data has been used for different States and in some cases a group of smaller States/UTs have been clubbed together to effectively use the supplementary data for improvement of estimates.

The paper also uses spatial models which exploits the neighbourhood relation between districts to further strengthen the district estimates depending on the significant spatial autocorrelation. Finally state wise thematic maps of monthly district income of agriculture households have been made to visualise the disparity amongst the districts. Estimates have been obtained through R Package on Small Area Estimates and the district maps through bharatmaps.gov.in/makemymap.

Keywords: *Agriculture households, direct survey estimates, linear mixed models, spatial models, spatial autocorrelation.*

Selection indices for green forage yield of *Cenchrus setigerus* genotypes

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Abstract

The investigation "Selection indices for forage yield in *Chenchrus setigerus* genotypes" was carried out to study the variability, correlation and path coefficient for the green forage yield and yield contributing characters. Twenty seven genotypes of *cenchrus setigerus* were evaluated at field of Grass Breeding Scheme, Mahatma Phule Krishi Vidyapeeth, Rahuri during Kharif-2022-23 in a Randomized Block Design with two replications. The observations were recorded on forage yield and 13 yield contributing traits.

The analysis of variance revealed the significant difference among the genotypes for all the thirteen characters. A wide range of variability was observed for almost all the characters studied. The characters viz., crude protein yield/ plant, dry matter yield, green forage yield, stem and number of leaves showed high estimates of GCV and PCV indicating ample variability for these characters.

The traits viz., dry matter yield, crude protein yield, green forage yield, stem girth, number of leaves, leaf: stem ratio, crude protein and dry matter content showed high heritability estimates accompanied with high genetic advance percent of mean which indicates that the inheritance of these characters are due to additive gene action and direct selection for such traits is rewarding in crop improvement.

The character dry matter yield followed by crude protein yield, leaf breath, and days to 50 % flowering showed high positive direct effect on green forage yield. Considering correlation coefficient and path analysis simultaneously, dry matter yield, crude protein yield and leaf breath were found to be true components of green forage yield in *cenchrus setigerus* and emphasis should be given on these characters for green forage improvement in the present set of genotypes.

Keywords: *Forage yield, cenchrus setigerus variability, path analysis*

Antimicrobial Resistance Gene Prediction for Ruminant using Metagenomic Data

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Abstract

Antimicrobial Resistance (AMR) is a natural feature of microbial ecosystem in which microorganisms including bacteria, viruses, fungi, and parasites develop resistance to the drugs that were once successful in treating infections [1]. AMR genes if expressed, provide resistance to its host. Now a days it is of a great public health concern as these AMR genes are easily transmitted to plants, animals and humans via food chains. Ruminants such as cattle, goat and sheep have long been described as the major reservoir of AMR [4]. The genetic variations of widespread AMR have been researched using metagenomic sequencing data. MG-RAST, MGnify, IMG/M and NCBI GenBank have been used for the dataset preferably for ruminants [3, 5]. Then antimicrobial resistance is monitored using already available method which help to analyse patterns in data on antimicrobial use and resistance to predict which microorganisms are likely to develop resistance to specific type of drug. The findings play a crucial role in understanding the genetic basis of AMR. This aids in making quicker and more efficient response of healthcare professionals in developing strategies to combat this global health concern [2].
Keywords: *Antimicrobial Resistance, Metagenomic data, AMR Gene*

Blockchain Solutions for Ensuring Seed Purity and Traceability in Agriculture

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Abstract

This research paper presents the development and implementation of a cutting-edge seed traceability system tailored for the agricultural landscape of Chhattisgarh, India. The system, a collaborative effort led by Indira Gandhi Agriculture University, harnesses the technical expertise of the National Informatics Centre (NIC) to empower local farmers through enhanced transparency and accountability in the seed supply chain.

In response to the unique challenges faced by Chhattisgarh's agricultural sector, the blockchain-based seed traceability system leverages distributed ledger technology to record and authenticate the entire journey of seeds from production to distribution. The collaborative framework ensures the integration of smart contracts, enabling automated and secure transactions at each stage of the supply chain. The paper delves into the technical intricacies of the developed system, highlighting its decentralized architecture, cryptographic security measures, and user-friendly interfaces tailored for farmers. Through the utilization of this innovative technology, the traceability system not only ensures the authenticity and purity of seeds but also facilitates real-time monitoring and data access for farmers.

The proposed system has the positive impact of the seed traceability system on the agricultural ecosystem of Chhattisgarh, fostering trust among farmers, seed producers, and distributors. This research contributes to the evolving landscape of agricultural technology by showcasing a practical implementation of blockchain for seed traceability. The collaborative initiative aims to empower Chhattisgarh's farmers with a tool that not only enhances the integrity of seed supply chains but also fosters sustainable agricultural practices in the region.

Empowering Agriculture with Computer Vision: AI-based Renting and lending of Farm Implement System

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Abstract

This research paper presents a groundbreaking initiative aimed at enhancing the income of farmers in Chhattisgarh through the development of an innovative mobile application. The mobile app serves as a user-friendly platform that connects farmers in need of specific agricultural tools with those willing to lend or rent them. Leveraging advanced AI algorithms, the system ensures accurate and efficient identification of various farm implements, streamlining the process of matching supply with demand. This approach not only promotes resource-sharing within the farming community but also contributes to the overall optimization of agricultural operations. Indira Gandhi Agriculture University's technical collaboration with NIC underscores the commitment to harnessing technology for the socio-economic upliftment of farmers. The collaborative

effort addresses the challenges faced by the farming community in accessing and affording essential equipment, thereby fostering a more equitable distribution of resources. The AI-based system enhances the efficiency of the lending and renting process, providing farmers with a cost-effective solution to meet their agricultural needs. By promoting a sharing economy model for farm implements, the initiative aims to reduce financial burdens on individual farmers, ultimately leading to increased productivity and income.

This proposed solution discusses the development, implementation, and initial outcomes of the AI-enabled mobile app, emphasizing its potential to revolutionize agricultural practices in Chhattisgarh. The efforts showcased herein serve as a model for leveraging technology to empower farmers and foster sustainable agricultural practices in the pursuit of improved livelihoods.

Rainfall Distribution and Trends Analysis in the Navsari District, Gujarat

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Abstract

The study of rainfall variability is effective for agricultural planning, particularly in the context of evolving climate scenarios. The increasing attention to climate change underscores the long-term impact it poses on agricultural production. Rainfall distribution analysis to understand the patterns and trends, facilitating improved crop management strategies in the face of climate variability. This research focuses on analysing the rainfall variability in the Navsari area, employing a multi-faceted approach. Descriptive statistics provide insights into the distribution of rainfall, while the Mann-Kendall test is employed to discern trends over time. Additionally, the Standard Precipitation Index (SPI) is calculated to determine the degree of wetness in the region. Results indicate an inconsistency in rainfall distribution across the Navsari area. The monsoon season exhibits a significant increasing trend, with particular emphasis on the month of September, which has shown a consistent upward trajectory over the last four decades. SPI calculations reveal a notable shift towards extremely wet months in the past

decade. These findings have significant implications for agricultural practices in the region. Understanding the evolving patterns of rainfall allows for more informed decision-making, aiding farmers and policymakers in adapting to the changing climate. The identified trends, especially the increasing wetness during specific periods, offer valuable insights for sustainable and resilient agricultural practices in the Navsari area.
Keywords: *Mann-Kendall test, Rainfall Variability, Standard Precipitation Index*

IoT Enabled Smart-Farm Monitoring Device for Crops using LoRa Technology

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Abstract

Smart Farming and precession agriculture are defined as the high yield of crops with precise resource utilization in automation mode. The Internet of Things (IoT) and cloud computing are anticipated for remote communication between the device and the users. Various technology is used in machinery, equipment, and different kinds of sensors for soil monitoring, water monitoring, nutrient monitoring, pest monitoring, environment, farm implements, the use of robots/drones, and artificial intelligence in farming. In the far-flung areas, the internet is the bigger issue, by using the Internet of Things (IoT) and long-range (LoRa) technology we can solve the problem of the internet and send the data to the nearest end of the receiver device where the internet is there. LoRa technology is low-power and low-cost modules and transfers a data range of up to 2 km to 10 km without internet. In this paper, an IoT-enabled smart-farm monitoring device model is prepared to assist farmers in making their own decisions and getting more productive results. The smart-farm monitoring device model measures eleven parameters namely N, P, K, PH, EC, (at 15 cm), three-level moistures at 15 cm, 30 cm, 45 cm, and three-level temperatures at 15 cm, 30 cm, 45 cm of soil depths. Our model sends these parameters from the transmitter node to the receiver node using the LoRa technology. The data from the receiver node are transmitted to the cloud and then forwarded to the network server through a single gateway. The soil data detected by our module is readable through our web server page. The primary goal of this paper is to assist farmers in monitoring their farms for a better understanding of crops and get more productive results.

Keywords: *Agriculture; Soil Health Information; Smart Farming; IoT; LoRa; Sensors;* Advanced Agriculture Practices; *Wireless Communication.*

Price adjustment in Gujarat Cumin markets: A cointegration analysis

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Abstract

Spatial market performance can be measured in terms of the relationship between the prices of geographically separated markets because market integration is concerned with both temporal and spatial integration. Additionally, spatial price behavior in regional markets can be used as a gauge of overall market performance if price changes in one market fully reflect price changes in another. The long run and short run integration of Gujarat's cumin markets are assessed in this study using a co-integration technique within the framework of a vector error correction mechanism (VECM). Between January 2005 and December 2021 (17 years), data on the monthly wholesale price of cumin in India (in Indian rupees per quintal) was gathered from the Ministry of Agriculture and Farmers' website (https://agmarknet.gov.in/) (Anonymous, 2021). From the data gathered, Unjha, Rajkot, Gondal, Halvad, Tharad and Jamnagar were chosen as the study locations for the Cumin monthly pricing data in order to look into price co-integration between India.

Keywords: *Stationarity, Market integration, Co-integration and short-run disequilibrium*

Tailoring genetic diversity of forage maize genotypes through principal component and cluster analysis

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Abstract

Fifty genotypes of forage maize were evaluated at the Main Forage Research Station, AAU, Anand, Gujarat during late Rabi 2021-22 for genetic diversity study based on eleven biometrical traits. To determine extent of variability existing among 50 forage maize genotypes, Principal Component Analysis (PCA), cluster analysis and the inter-relationship existing between biometrical traits through Pearsons's correlation analysis were carried out. The highest correlation was observed among the days to 50% tasseling and days to 50% silking, green yield per plant and the stem thickness. According to the principal component analysis, three principal components (PCs) had an eigen value more than unity and accounted to explain 76.29 per cent of total variance that exists among 11 traits. Days to 50% silking, Days to 50% tasseling, Number of leaves, Plant height, Leaf length, Leaf width and Green yield per plant were highly loading on PC1 whereas Dry matter percentage and Crude protein percentage were highly loading on PC2 and Leaf stem ratio was highly loading on PC3. Fifty genotypes were classified in to three clusters through the hierarchical cluster analysis method. Cluster I comprised a maximum number of genotypes followed by cluster II. Based on cluster analysis, it could be recommended that crosses could be made between the genotypes of cluster II and III which are most distantly related. Genotypes under cluster III had higher values for most of the traits. Intraclass correlation (R2) was the highest for days to 50% tasseling followed by days to 50% silking and green yield per plant indicating that these traits played an important role in divergence.

Keywords: *Forage maize crop, biometrical traits, correlation, PCA, cluster analysis*

Assessment of Genotype × Environment Interaction and Yield Stability in Paddy Utilizing Stability Parameters of AMMI Model via Simultaneous Selection Index

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Abstract

Developing new genotypes that combine high yield with reliable stability is a critical objective within breeding programs. An investigation into the interaction between genotype and environment (GEI) was conducted through a field experiment involving 30 genotypes across three distinct environments to identify paddy varieties with consistently high yields. The analysis of variance indicated that environmental effects were the primary contributor to variation, with GEI and genotype effects following in significance. An evaluation of the AMMI model for GEI underscored the substantial significance (P<0.01) of the first two interaction principal components (IPCA1–IPCA2). By leveraging these notable IPCAs, 12 AMMI stability parameters were computed alongside simultaneous selection for both yield and stability (SSI). The SSI () process identified genotypes G23 (Gurjari (C)), G27 (GAR-3 (C)), and G15 (NVSR-722) as the most reliable high yielders, while G13 (NVSR-2965) was recognized as the least stable, exhibiting low yields. Stability measures such as SIPC, MASI, and MASV can be effectively employed to further enhance the identification of stable, high-yielding genotypes. This holistic approach combines statistical analyses with stability parameters to pinpoint promising genotypes that display both high yield and stability across various environments.

Keywords: *G × E Interaction, AMMI, MASV, SSI, Stability*

A Statistical Analysis on Instability, Growth and Seasonal Component in the Price Series of Major Castor Markets in Gujarat

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Abstract

The present study was carried out by using time series data of price from 2005 to 2021, to compare the price variation, to measure the price instability and price seasonality of major castor markets of Gujarat i.e. Banaskantha, Mehsana, Patan, Rajkot, Sabarkantha, and Gandhinagar. Data were collected from AGMARKNET (Agricultural Marketing Information Network) Govt. of India. The price variation had been compared by using descriptive statistics. Range and standard deviation indicated wide variation in the price level in all the market. The price instability and price seasonality based on trend model were measured. All the six markets have positively skewed ($\gamma1 > 0$) and platykurtic ($\beta2 < 3$) distribution. Among the market under study, the seasonal indices of castor price were highest in August and lowest in May for the Mehsana, Banaskantha, Rajkot, Sabarkantha, and Gandhinagar market respectively. Estimates of fitted cubic trend model for Mehsana, Banaskantha, Rajkot, Sabarkantha, and Gandhinagar markets market and estimates of fitted compound trend model for Patam market were significant. Highest instability was observed for Patan market. The farmers and policy makers can use this price signal for their future plan.

Keywords: *Descriptive Statistics, Growth, Instability, Seasonality*

TS 2: Artificial Intelligence for Transforming Agriculture

INVITED TALK

Artificial Intelligence for Futuristic Farming

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Currently, several challenges confront the agriculture sector globally. These include more pronounced climate change and weather variability, depleting natural resources including land and water, deteriorating soil and water quality; and shortages of human resources for farming. Sustainable and more efficient agriculture practices and technological innovations are crucial for overcoming these challenges and ensuring a resilient, productive and efficient agricultural sector.

The important components of the sustainable agriculture are to ensure the precision farming that involves the application of right input in right quantity and of quality at right place and in right way; and streamline the agriculture supply chain that helps reduce food waste, improve the quality of harvested produce, make value added products and ensure timely delivery to markets. Traditional and conventional farming methods rely on generalized approaches that may lead to inefficient resource utilization. However, artificial intelligence (AI) technologies, such as machine learning algorithms, sensor networks, IoTs and autonomous machines (robotics and drones), empower farmers to make data-driven decisions in real time, tailor interventions to specific crop needs, optimize resource usage and enable them to implement the decisions with ease, timely and autonomously, as stated below.

Crop planning, management and predictive analysis: AI-driven analytics can play a pivotal role in crop assessment and management; and bio-mass and yield prediction. By collecting and analyzing enormous data and information, AI algorithms can identify patterns, forecast crop yields, and optimize planting and other farm operation schedules. This enables farmers to make informed decisions about crop selection, irrigation, and nutrition, ultimately maximizing yields and minimizing waste. AI-powered drones equipped with advanced sensors can monitor crop health, detect pests, and assess soil conditions, providing farmers with real-time insights to enhance decision-making. Predictive analytics also assist in early detection of potential issues, allowing for proactive interventions to prevent crop diseases and pest infestations.

Autonomous farming operations: Autonomous technologies driven by AI will be the backbone of the futuristic farms. Robotic systems and autonomous machinery can perform tasks such as seeding and planting, weeding, input application (water and nutrients) and harvesting with unparalleled precision and efficiency. AI algorithms enable the systems to identify; and machines to respond and adapt to changing conditions, improving the overall input use efficiency, productivity and profitability of the farm while reducing labor costs. Autonomous farming operations not only address labor shortages but also contribute to sustainable farming practices by minimizing the use of chemical inputs and resources.

Resource use efficiency: One of the critical challenges is the efficient use of resources to meet the growing global demand for food. AI can contribute to sustainability by optimizing resource management. Smart irrigation systems, for instance, use AI algorithms to monitor soil moisture levels and weather conditions, ensuring that water is applied precisely where, when and how-much it is needed. This reduces water wastage, conserves energy, and minimizes environmental impact. Similarly, AI-driven supply chain management helps reduce food waste by optimizing transportation routes and storage conditions, ensuring that harvested crops reach consumers in optimal condition.

Thus AI has the great potential to transform the “traditional farms” to “future farms” that are productive, profitable, resources use efficient, environmentally sustainable, and more importantly being integrated with the digital tools and technologies are attractive proposition for the technology suave human resources.

Application of Generative AI in Agricultural Knowledge Base Creation

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A shared understanding of the Agricultural domain, represented in terms of a knowledge base (KB) or knowledge repository, with machine precision, is a prerequisite for developing digital products and services that are interoperable. Such KBs are also useful in developing AI techniques such as identification of a disease in an article published on the web or in extracting an advisory from a scientific report. Likewise, responding to farmer queries about pest management requires careful consideration w.r.t the weather, diseases, applicable pesticides and their dosage. When this knowledge is represented in a KB, and advisories are codified using logical rules or modeled using ML techniques, delivering personalized, timely and accurate advisories is possible. However, developing and maintaining such KBs is resource intensive. We can bring down this cost by harvesting information compressed in Large Language Models (LLMs) by prompting, and using them to seed the KB, which can then be verified and expanded in a more cost-effective manner. Using this framework, we used GPT-3.5 turbo, by prompting it to mention all relevant entities (pest, diseases, pesticides) for a given crop and created an automated and extensible Knowledge Base. So far, we have a KB consisting of 29 crops, with 682 unique diseases and pests, 2682 symptoms and 730 control substances. We have used the KB to improve the precision and recall in several downstream applications with respect to information extraction from unstructured data sources. We have also created a mind map to guide this KB creation process, which takes a bird eye view of the agriculture domain w.r.t the problems to be solved.

Artificial Intelligence (AI) in Agriculture: Advancing Steps towards Sustainability

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Over the past two decades, the intersection of Artificial Intelligence (AI) and agriculture has witnessed a symbiotic relationship. Numerous AI theories have been methodically applied to address agricultural challenges, while reciprocally, agricultural experiments have significantly contributed to the advancement of AI theories. This collaborative development is enhancing the sustainability of agriculture. AI has pervasively influenced various facets of agriculture, and this article delves into five key aspects of this convergence. AI-DISC (Artificial Intelligence Based Disease Identification for Crops) and AI-DISA (Artificial Intelligence Based Disease Identification in Animals), mobile applications designed to address disease diagnosis in crops and livestock respectively using AI. Utilizing state-of-the-art deep learning models, these mobile apps are deployed on globally standardized GPU servers, offering farmers prompt and efficient responses. An additional facet involves the dissemination of vital livestock information to farmers, addressed by an AI-based chatbot named Shria (Smart Heuristic Response based Intelligent Assistant). Currently, it caters to inquiries related to cattle, goats, and sheep, leveraging natural language processing capabilities. PLW (Pig Live Weight) is another mobile application which is also backed by AI algorithms for estimating and monitoring the live pig weight. Apart from this real time AI based response, AI is also substantially contributing in the area of crop improvement through high throughput phenotypic trait analysis. In this area, the applications namely, SpikeSegNet, SlypNet, PanicleDet, MuSic (Mustard Silique Counter) v1.0 "m—Senescencica" are significant. These models addresses the yield estimation through ear, panicle and silique segmentation and counting. The integration of AI into agriculture holds immense potential to enhance productivity, reduce environmental impacts, and promote sustainable farming methods. With AI, farmers can make data-driven decisions, improve crop yields, optimize resource usage like irrigation water, and play a pivotal role in ensuring global food security. Therefore, incorporating AI into agriculture stands as a promising avenue to revolutionize the industry and usher in a more sustainable and resilient future.

ABSTRACT

Trained GPT models for knowledge delivery in agriculture

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Abstract

In the age of sustainable smart agriculture, a substantial volume of agricultural news text is shared on the internet, contributing to the accumulation of substantial knowledge in agriculture. The application of fine-tuning methods on pre-trained language models (PLMs) has proven to yield substantial enhancements in performance. However, these techniques encounter various intricate challenges, such as a scarcity of agricultural training data, limited domain transferability, and the intricate and costly deployment of large models. Motivated by the achievements of Generative Pre-Trained Transformer (GPT) models, this study investigates the possibilities of utilizing GPT in agricultural informatization. GPT models are not trustworthy. So, training the GPT model increases the accuracy. Traditional fine-tuning is done to train a model on a specialized dataset. The dataset consists of conversations formatted in a JSON lines structure, where each exchange is a sequence of chat message dictionaries. Each dictionary includes role assignments (system, user, or assistant) and the corresponding content of the message.

This approach aims to adapt the model to understand better and generate human-like conversations. Findings reveal that the GPT model successfully tackles challenges and establishes it as a suitable solution for agricultural text classification. With the power of fine-tuning at your disposal, the possibilities for AI-driven solutions are limitless, promising a brighter future for AI technology in agriculture.

Enhancing Agricultural Price Predictions: The Interplay of Hidden Markov Models and Deep Learning Techniques

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Abstract

Forecasting agricultural commodity prices, particularly amidst inherent complexities like perishability, seasonality and production variability, is crucial. This research pioneers an innovative hybrid model, combining Hidden Markov Models (HMMs) with Deep Learning (DL) architectures, tailored for nonlinear, nonstationary agricultural price data. The model is enhanced with technical indicators: Moving Average (MA), Bollinger Bands (BB), Moving Average Convergence Divergence (MACD), Exponential MA (EMA), and Fast Fourier Transformation (FFT). HMMs proficiently manage sequential intricacies, while DL discerns complex data patterns. This dual approach addresses DL's generalization challenges. Employing the Potato price dataset from Champadanga, West Bengal, six DL models - RNN, CNN, LSTM, GRU, BiLSTM, BiGRU are integrated with HMM. Performance metrics (RMSE, MAPE, MAE, and the Diebold-Mariano test) confirm the hybrid's superiority over traditional models across 1, 4, 8 and 12-week forecast horizons. This breakthrough holds immense potential for stakeholders, policy makers for revolutionizing agricultural commodity price predictions.

Big Data Analytics for Transforming Indian Agriculture

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Abstract

In the 21st century, Big Data analytics has emerged as a game-changer, reshaping industries worldwide, and India's agriculture sector is no exception. Agriculture has stepped into the realm of big data, where analytics works like magic in decision-making. This transformation brings about intelligent solutions for crop disease, yield forecasting, crop planning, and more. This study explores the transformative impact of Big Data Analytics on Indian agriculture, highlighting key studies and findings. It discusses the application of frameworks using technologies like Hive, Hadoop, and data clustering for crop disease solutions, yield forecasting, and crop planning. The integration of IoT, AI, and data-driven platforms like KRISHI and GRANULAR is emphasized. Some Big data platforms that relevant to agricultural data in India are AgriAnalytics, CropIn, Microsoft FarmBeats, IBM AgroPad, Taranis etc. Major findings include the identification of high-priority solutions for crop diseases, location-specific frameworks for forecasting, and the role of data clustering in enhancing agricultural production. Challenges in adopting big data analytics in agriculture, such as security and technical knowledge, are acknowledged. The review concludes with insights into the emergence of smart agriculture, underlining the potential of Big Data to address sustainability issues in the Agri-food supply chain.

Keywords: *Big data, Big data analytics, Agriculture, Transforming, Smart agriculture, decision making, precision farming etc.*

Innovative Multivariate Deep Learning Frameworks for Forecasting Volatile Indian Onion Market Prices

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Abstract

Forecasting agricultural commodity prices, especially in the context of volatile markets like onions in India, presents significant challenges due to the intricate nature of the agricultural system and the inherent characteristics of noisy, non-stationary, and complex time series data. Conventional statistical models, while interpretable, struggle to attain high precision in the dynamic agricultural landscape. In recent years, artificial intelligence (AI) based machine learning and deep learning techniques have gained prominence in time series modelling and agricultural commodity price forecasting. However, there is a scarcity of research specifically focusing on deep learning frameworks for onion price forecasting in the agriculture domain. A robust machine and deep learning model can offer valuable early warning signals, enabling better management of onion price movements and uncertainties. Within the time series literature, incorporating external information has been shown to enhance model efficacy and predictive accuracy. Despite this, an in-depth investigation of the current state of research reveals that the integration of external information through deep learning models in the agriculture domain remains relatively limited. Consequently, these identified research gaps have piqued our interest in undertaking the present investigation and documenting the resulting findings. This study aims to develop a multivariate deep learning modelling framework, namely Long-Short Term Memory (LSTM), Convolutional Neural Network (CNN), and attention mechanism-based multivariate LSTM model, for onion price forecasting using weekly data from major onion consumer markets, in conjunction with available external sources of information. The study also places emphasis on selecting relevant features to enhance the predictive performance of the deep learning model, employing the random forest feature selection algorithm. Finally, the results are compared with a univariate Generalized Autoregressive Conditional Heteroscedastic (GARCH) model, as well as a time delay neural network (TDNN) and univariate LSTM model, to demonstrate the predictive ability of the proposed deep learning framework. Performance evaluation metrics, such as mean absolute error, root mean square error, mean absolute percentage error, directional

statistics, and relative root mean square error, are utilized to assess the prediction accuracy and efficiency of the developed onion price forecasting model.

Keywords: *Onion, Price forecasting, Volatility, Deep learning, LSTM, CNN, Attention mechanism*

Remote Sensing & Deep Learning Based Mango Tree Counting

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Abstract

Mango is a fruit of great economic importance in India. India shares about 50% of the world's mango production and ranks first among the world's mango producing countries. Being an evergreen and deep-rooted tree, it has adopted to fix carbon under large seasonal variation of light and water. In order to estimate the production capacity of the insured orchards, an extensive inventory is conducted in situ every three years. The inventory includes counting number of trees, classifying them in production categories and evaluating damaged ones. Satellite Remote Sensing proves to be a vital tool for estimating ecological parameters such as population density, tree health, volume, biomass, and carbon sequestration rates. The significance of tree counting extends beyond orchard evaluations, playing a pivotal role in diverse applications such as environmental protection, agricultural planning, and crop yield estimation. However, traditional tree counting methods often require expensive feature engineering, resulting in additional mistakes and limited overall optimization. To address these challenges, recent advancements have seen the adoption of deep learning-based approaches for tree counting, demonstrating state-of-the-art performance in this important task. This paper introduces a novel approach employing deep learning for Image-Based Mango Tree Counting in high-resolution satellite imagery data. The proposed model, named Bi-directional Feature Pyramid Network (BiFPN)-YOLOv8, employs object detection to effectively separate, locate, and count mango trees within orchards. Training the network involved using a dataset comprising total of 200 images of mango orchards. Experimental results demonstrate that the proposed method consistently outperforms state-of-the-art methods, even in challenging conditions.

Keywords: *Inventory, Remote Sensing, Deep Learning, BiFPN-YoloV8*

Application of ANN model for Technology Impact Assessment in Bihar

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Abstract

Agricultural technologies are helping farmers in enhancing their farm productivity and livelihood. Climate smart technologies like Zero Tillage (ZT) and climate resilient high yielding crop varieties minimise the farmer's production risks under changing climatic conditions. Artificial Neural Network (ANN), a machine learning tool is widely used for complex data analysis in research over the last few decades. In this study Climate Resilient Agricultural (CRA) technologies have been assessed at farmers' fields in five villages of Gaya district of Bihar by ICAR RCER, Patna. ZT technology along with high yielding varieties of rice, wheat and green gram were demonstrated in more than two hundred farmers' fields along with recommended plant protection measures during 2020 to 2022. Rice-Wheat-Green gram cropping system adopted by seventy-five farmers were randomly selected. Data collected on fourteen variables like yield, cost of cultivation parameters, plant protection parameters, net income and benefit cost (B: C) before and after technological interventions using designed interview schedule. Data analysed by ANN approach using R package. Results indicated that demonstrated CRA technologies significantly ($p<0.05$) increased yield, net income and B: C ratio and decreased cost of cultivation. ANN model performed well and showed accuracy nearly 98%. Simultaneously, model also identified the land preparation, seed procurement, B:C ratio and net income as the major component which had significant impact in the farmer's field. Hence, ZT along with climate resilient varieties found to improve the farmers yield and income considerably.

Keywords: *ANN, CRA technologies, Bihar, Zero Tillage*

Integrating Artificial Intelligence (Ai) and Geospatial Technology for Estimating Soil Fertility

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Abstract

The integration of Artificial Intelligence (AI) and Geospatial Technology has emerged as a promising avenue for addressing the complex challenges associated with estimating soil fertility. The present study combined advanced AI algorithm with geospatial data to enhance the accuracy, efficiency, and scalability of soil fertility assessments by digital soil mapping (DSM). DSM primarily makes use of machine learning algorithms to identify relationships between soil properties and multiple covariables that can be detected across the landscapes. To carry out the present study, a total of 66 geo-referenced data points from a depth of 15-30 cm were collected from reliable sources. Various parameters of the soil such as pH, EC, OC, P, K and S were taken under study. The data points were then interpolated using open source GIS software. As a result of interpolation, the data points increased to approximately 20,000 and interpolated maps were obtained. The interpolated maps were studied to predict the value of the parameter at the unsampled locations of the study area and fertility maps based on same were obtained.

Keywords: *Interpolation, Machine learning, Soil Mapping, Geospatial*

Aspect-Based Sentiment Analysis in Education: A Review

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Abstract

Aspect-based sentiment analysis is a more advanced version of traditional sentiment analysis that divides the text into various aspects and assesses the sentiment associated with each. This review paper presents a comprehensive assessment of current literature to examine the approaches, tools, and improvements in aspect-based sentiment analysis techniques specifically targeted for educational situations. The effectiveness of aspect-based sentiment analysis in capturing complex sentiments, as well as its impact on key educational factors such as student engagement and learning outcomes, has been investigated. Furthermore, the review addresses challenges such as subjective interpretations and cultural differences, providing possible solutions and suggesting future research directions. The gaps in current aspect-based sentiment analysis techniques in education have been identified, emphasizing the need for novel methodologies. This paper aims to serve as a comprehensive resource for researchers, educators, and practitioners, providing valuable insights into the current state of aspect-based sentiment analysisin education and inspiring further advancements in the understanding and application of sentiment analysis in educational settings.

Keywords: *Aspect-Based Sentiment Analysis, Sentiment Classification, Student Feedback, Natural Language Processing.*

Maize leaf Nitrogen Status Estimation in Maize using Artificial Intelligence

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Abstract

Now the world is experiencing revolutions in agriculture 5.0 due to artificial intelligence (AI), machine learning based decision-making systems for resource use efficiency and overall sustainability. AI can be applied for assessing soil and crop nutrient status where AI algorithms assess the images captured by remote sensors or digital cameras and calculates variations within a field, generating a nutrient map which enables to diagnose the crop nutrition status which provides information on the supply of

nutrients to plants. Hence an attempt was made to estimate the maize leaf nitrogen status using artificial intelligence. The experiment was conducted during rabi-2020-21, at University of Agricultural Sciences, Dharwad, Karnataka, India. The experiment was laid out in randomized complete block design comprising of nine graded levels of nitrogen (Absolute control, 25, 50, 75, 100, 125, 150, 175 and 200% RDN), replicated thrice. The organization used by the developed model is typically picture acquisition, processing and classification. For classification, self-acquired real-time images of the maize leaves were captured from the experimental plots receiving varied levels of nitrogen. The images of leaves were captured from 15 DAS up to 90 DAS at frequent intervals (weekly twice) from different levels of nitrogen applied plots. Large number of images were collected during rabi season which were used as dataset to develop a model. AI based algorithm developed using Convolutional Neural Network (CNN) with programming language of python achieved a maximum accuracy of 76.3 per cent in detection of the maize leaf nitrogen status of maize.

Keywords: *Algorithm, Artificial Intelligence, Convolutional Neural Network, Maize, Nitrogen*

Future Opportunities and Challenges of Artificial Intelligence in Agriculture Sector

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Abstract

Artificial Intelligence (AI) is a transformative field within computer science that has made significant strides in recent years. AI has become a popular technology of the era due to transform business and many filed. New a day, researchers and scientists are now moving toward the utilization of new IoT technologies in smart farming to help farmers use AI technology in the development of improved seeds, fertilizers use efficiency, crop protection, crop monitoring, predictive analytics and agricultural robotics etc. This will improve farmers' profitability and the overall economy of the country. In this regard, farmers are increasingly adopting the use of sensors and soil sampling to gather data to be used by farm management systems for further investigations and

analyses. But, on other hand farmers face several challenges when applying AI in agriculture such as, cost, lack of knowledge regarding to AI machine, lack of access to technology and training data generation and data collection, privacy issue etc.,

Keywords: *Artificial intelligence, opportunity, challenges, Agriculture*

Artificial Intelligence (AI) powered Soil Quality Monitoring in Agricultural Systems

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Abstract

Artificial intelligence is the simulation of human intelligence processes by machines, especially computer systems. In recent years, the world has witnessed rapid advancements in agricultural technology, revolutionizing farming practices. These innovations are becoming increasingly essential as global challenges such as climate change, population growth together with resource scarcity threaten the sustainability of our food system. Introducing AI solves many challenges and helps to diminish many disadvantages of traditional farming. Artificial intelligence in agriculture can help explore the soil health to collect insights, monitor weather conditions, and recommend the application of fertilizer and pesticides. Farm management software boosts production together with profitability, enabling farmers to make better decisions at every stage of the crop cultivation process. The AI in agriculture market is expected to grow from USD 1.7 billion in 2023 to USD 4.7 billion by 2028, according to MarketsandMarkets. Artificial intelligence continue to evolve at a rapid pace, with many potential applications related to soil science. Thus, researchers have focused on developing models for estimating soil quality based on artificial intelligence techniques for the processing of multidimensional data from agro- industrial systems, which provide useful information for farmers about soil management and crop conditions. The wrong combination of nutrients in soil can seriously affect the health and growth of crops. Identifying these nutrients and determining their effects on crop yield with AI allows farmers to easily make the necessary adjustments. AI algorithms can analyze the chemical composition of soil samples to determine which nutrients may be lacking. AI is sure to play an increasingly large role in agriculture and food sustainability over the coming years, even to monitoring variables like soil quality, it could transform the global food supply chain. Intelligent

machines like artificial intelligence and machine learning can transform basic data inputs into beneficial information.

Keywords: *Artificial intelligence, Agriculture, Soil Quality Monitoring, Sustainability*

Forecasting Rubber Prices in Kerala Using LSTM Deep Learning Techniques

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Abstract

The rubber industry plays a pivotal role in the economy of Kerala, India, contributing significantly to agricultural output and employment. As the rubber market is characterized by volatility and complex dynamics, accurate price forecasting is essential for informed decision-making by stakeholders. This study employs Long Short-Term Memory (LSTM) deep learning techniques, a subset of recurrent neural networks (RNNs), to forecast rubber prices in Kerala. The proposed LSTM model is trained on historical weekly rubber price data starting from January 2002 to November 2023, capturing intricate temporal patterns and dependencies that traditional forecasting methods may overlook. The LSTM model demonstrated its ability to learn and adapt to non-linear patterns inherent in rubber price time series data. The research evaluates the model's performance through rigorous testing, comparing its predictions against actual market data. The findings highlight the LSTM's proficiency in capturing short and long-term trends, making it a valuable tool for forecasting rubber prices in Kerala. This study contributes to the existing literature on agricultural commodity price forecasting by showcasing the effectiveness of LSTM deep learning techniques in a real-world scenario. The outcomes of this research offer valuable insights to rubber industry stakeholders, policymakers, and investors, aiding them in making informed decisions and mitigating risks associated with price fluctuations in the Kerala rubber market. Additionally, the methodology and insights gained from this study can be extended to other agricultural commodities, panviromoting the application of advanced deep learning techniques in agribusiness forecasting.

Machine Learning-Based Comparative Analysis of Weather-Driven Rice and Sugarcane Yield Forecasting Models

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Abstract

This study investigates the use of various machine learning algorithms for predicting rice and sugarcane yields for Navsari district of Gujarat, India. Recognizing the critical role of weather in crop productivity, accurate forecasting becomes essential for effective resource management. In methodology, weekly averages and weighted weather indices were computed based on daily weather data to develop forecast models using machine learning algorithms such as Random Forest, Support Vector Regression, KNN, XGBoost, Gradient Boost, and Decision Tree. Results show that Random Forest and Gradient Booster algorithms outperform others in rice yield forecasting, while Gradient Booster and XGBoost demonstrate high accuracy in sugarcane yield prediction. However, the Mean Absolute Percentage Error (MAPE) values remained above 8%, indicating room for improvement. The study recommends integrating additional datasets, such as remote sensing-based vegetation indices, to enhance predictive capabilities. Overall, the findings contribute valuable insights for stakeholders, including agricultural planners, policymakers, and researchers, emphasizing the need for continued refinement and validation of models to optimize agricultural planning and decision-making in this region.

Keywords: *Machine learning, Yield forecasting, Random Forest, Booster, Sugarcane and Rice*

A Comparative Study on Deep Learning Models for Insects Pests Classification in Tomato Crop (*Solanum lycopersicum*)

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Abstract

The annual loss due to damages caused by Insects Pests in Indian agriculture is nearly 15.7% which accounts for US $36 billion and 10.8% in the World. They pose a threat to vegetables by causing damage through feeding, contamination, and disease transmission, results in poor yield, quality, and productivity. Tomato, one of the most important vegetable crops of India, grown in 789.20 thousand ha area with 25.00mt/ha productivity. Insects and Pests are biotic constraints to tomato production such as tomato fruit borer (*Helicoverpa armigera*) alone causes heavy loss and other insects like mealy bug (*Phenacoccus solenopsis*) also damages the crop. This study aims to employ deep learning models for the classification of crop insect pests, comparing four standard models: VGG 16, DenseNet 169, MobileNet, ResNet 50 V2. The Evaluation of these models is based on metrices such as Accuracy, Precision, Recall and F1 Score to determine their performance in insect pest classification.

Keywords: *VGG 16, DenseNet 169, MobileNet, ResNet 50 V2, Accuracy, Precison, Recall, F1 Score.*

Satellite based acreage estimation of mango orchards using decision tree algorithms

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Abstract

India is second largest fruit producer in the word and mango (*Mangifera Indica* L.) major fruit crop grown in India. Mango is a very important fruit that is liked by the majority of the population due to its nutritional value. Accurate information is required for policy decision-making in terms of providing subsidies, area expansion, and crop insurance planning. Hence, this type of information may be retrieved through satellite images by using image classification techniques, which is the main source of information retrieval about the crop production and it also forms the basis and is an important step for crop cover classification, crop identification, acreage estimation, assessment of crop health and/or crop stress, change detection, yield prediction etc. There are several methods for satellite image classification such as ISO-DATA, K-Means, Maximum Likelihood, Minimum Distance, Artificial Neural Network (ANN), Support Vector Machine (SVM), and Decision Tree Classification (DTC), etc. Decision tree is one of the inductive learning algorithms that generate a classification tree to classify the data. It is based on the “divide and conquer” strategy. The classification tree is made by recursive partitioning of the feature space, based on a training set. At each branching, a specific decision rule is implemented, which may involve one or more combinations of the attribute inputs or features. Decision Tree Classification (DTC) is a non-parametric supervised learning algorithm, which is utilized for both classification and regression tasks. In recent years, the use of decision tree classifier for land cover classification of satellite data has increased considerably, because decision tree classification is a computationally efficient algorithm. The classification of orchards using satellite data processing can provide supplementary facts for management decision-making, such as the assessment of fruit yield, the quantification of proper fertilizer application, irrigation needs, and the application of pesticides for pest and disease management. This satellite-based approach stands as a cost-effective alternative to traditional field survey-based

methods, offering a timely and efficient means for crop area estimation and decision support in agriculture.

Keywords: *Classification, Decision tree, Satellite images*

Predictive modelling of kisan query call volumes in Agriculture using Artificial Intelligence (AI) techniques

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Abstract

In the current situation, it is imperative to investigate new avenues for obtaining precise knowledge about issues pertaining to agriculture. In this regard, a multi-phase methodology is suggested to carry out time series analysis and spatial mapping on the more than 1.6 million call log records from farmers' helplines that have been made available by the Indian government under Ministry of Agriculture and Farmers' Welfare. With regard to crops from several Karnataka zones, the zone-wise density of farmers requesting assistance is shown using the suggested Zonal analysis framework. Moreover, the suggested step-plot idea provides information on the duration of issues in the agriculture industry. Furthermore, the study compares the forecasting performance of different Machine Learning and Deep Learning-based models to estimate the crop-wise demand for help by the producers of target zones. The experimental results convey that the proposed framework is useful for predicting trends in farmers' problems and helps in policy recommendations regarding agriculture extension and other related domains.

Keywords: *Farmer's query, Artificial intelligence in agriculture, Data mining in agriculture, Big Data, Deep Learning, kisan call center, Spatio temporal analysis.*

Machine learning Technique for Price Forecasting of Tomatoes: A Case Study of Karnataka

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Abstract

The perishable nature of tomato leads to high fluctuations in its price based on supply and demand. The availability of timely and accurate forecasts of the price helps farmers make informed decision and they may have options to sell their produce to alternative nearby markets to fetch good prices. Several statistical models have been applied in past for forecasting price of different agricultural commodities; however they have limited applications with their own sets of assumptions. Of late there have been rise in use of machine learning techniques for forecasting purposes. The present study attempts to explore random forest algorithm tp forecast price of tomatoes in different markets of Karnataka. The forecasts obtained by random forest were compared with the stochastic model i.e., Autoregressive Integrated Moving Average (ARIMA) model. Different accuracy measures viz, root mean square error (RMSE) and mean absolute error (MAE) and Mean Absolute Prediction Error (MAPE) are used to evaluate the results of both the models and it is found that Random Forest outperformed ARIMA.

Keywords: *Tomato; Forecasting; Machine Learning; Statistical model*

TS 3: Survey Methodology for Field Crop Yield Estimation

INVITED TALK

Survey Methodology for Field Crop Yield Estimation

Amrish Antre
Senior- Agronomist

Precisely forecasting crop production is essential for developing efficient farming practices and preserving food security in a rapidly changing world. Crop yield influences food productivity and is crucial in guaranteeing food availability and safety. To improve national food security, import and export decisions are made in a timely manner by policy makers based on precise forecasts. Indian Agriculture is a unique set up. Due to various factors, like small land holding size, diverse geographic and soil properties, weather conditions, farmers literacy, availability of data, crop yield prediction is a challenging task. Various limitations of the assessment due to data reliability, imperfect remote sensing methods, lack of education and incentives for clean and honest data. There are few existing methodologies used for crop yield estimation, like stratified random sampling field surveys and CCEs (crop cutting experiments). However, challenges include the accuracy of farmer-reported yield (bias reporting), strongly oppose by farmers for conducting CCEs, influenced CCEs, and a labor issue. Hence data compilation needs to be adjusted to these unique features. Educating farmer as a primary data provider, Combination of remote sensing, manual truthing and data compilation for future AI based assessments. Remote sensing backed by reliable ground truthing, database-driven artificial intelligence system, weather-based yield modelling, Govt. initiatives to digitize agriculture and implement smart farming practices, increase collaboration among stakeholders (Farmers, Agri department, researcher and technology providers) are some trends which shape the future for crop yield estimation.

Use of Technology in crop Yield estimation

Dr. Sunil Kumar Dubey
Deputy Director, Mahalanobis National Crop Forecast Centre

Crop yield estimation is crucial for agriculture, informing various aspects like resource allocation, risk management, and policy decisions. Traditionally, assessing crop yield has been a labour-intensive and time-consuming process, relying heavily on manual field surveys (*i.e* CCE). However, the emergence of remote sensing technology and advanced computational algorithm has revolutionized this domain, offering a precise, efficient, and data-driven approach to yield estimation.

Nowadays satellite remote sensing has become an effective way of making yield predictions due to its advantages of simple data acquisition, low cost, efficiency, wide spatial coverage, and short operating cycles.

Currently different approaches *i.e*. Weather based empirical models, Remote sensing based empirical models are being used to estimate yields for major field crops under the FASAL Project of the Department of Agriculture & Farmers Welfare.

Further, towards enabling large scale adoption of technology-based yield estimates in PMFBY system for crop loss assessment, DA&FW has conceptualised Yield Estimation System based on Technology (YES-TECH) under Pradhan Mantri Fasal Bima Yojana. The models envisaged for technology-based yield estimation under this scheme is Semi-physical models, AI/ML models, Crop simulation Models, Ensemble models, parametric index of crop performance.

Agriculture Statistics and new initiatives

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In India, agriculture plays a crucial role in the country's economy, providing livelihoods to a significant portion of the population. Agriculture statistics in India are essential for monitoring and assessing the performance of the sector. The data encompass various aspects such as crop production, land use statistics, etc. Ministry of Agriculture & Farmers Welfare compile releases the crop production estimates of major agricultural crops in the country. In recent years, there has been a growing emphasis on leveraging technology to enhance the accuracy and efficiency of agricultural data collection. In pursuit of this objective the Ministry has started digital initiatives in crop area as well as crop yield estimation.

Integrated Sample survey for Crop Yield Estimation using advanced technologies

Dr (Mrs) Prachi Misra Sahoo
Principal Scientist, ICAR-IASRI

The information on Crop statistics is the backbone of the Agricultural Statistical System. The availability of reliable and timely crop estimates needed for important policy decisions on, pricing, procurement, storage, transportation, marketing, export/import, public distribution, investment planning and compilation of GDP in the country. The domain of agricultural statistics is majorly based on two parameters, the area and production estimation of principal crops. The former is obtained through complete enumeration whereas the latter through sample surveys. The estimates of crop production based on area through field enumeration and yield rate through crop cutting experiments (CCEs) conducted under General Crop Estimation Surveys (GCES). But this requires more transparency, accuracy and reduction in time lag in yield estimates generation process. In due course of time, many changes have taken place at national as well as at global level. These are mainly due to changes in the level of technology, government policies and structure of the population. Consequently, there are changes in data need and requirement. Keeping in view the changing scenario, it has been realized that there is a need for reappraisal of the methodologies developed for agricultural surveys. The recent technological developments in the space technology have shifted the emphasis of survey research work towards newer emerging areas of Remote Sensing technology and Geographical Information System (GIS). Further, with advancements in computational technology and Computational Intelligence techniques like machine learning techniques, Deep learning techniques etc can be applied to further strengthen these techniques. Therefore, a novel integrated methodology for crop yield estimation needs to be developed integrating advance Geospatial technology, Machine learning techniques, sample survey and various data types.

ABSTRACT

An efficient Exponential-type Family of Estimators for the Population Variance in Simple Random Sampling

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Abstract

This paper addresses the problem of estimating the population variance of the study variable y using the information of the auxiliary variable x. The bias and mean squared error of the proposed estimator are obtained upto the first order of approximation. The proposed estimator is more efficient than usual unbiased estimator s_y^2, Das and Tripathi (1978), Upadhyaya and Singh (1986), Garcia and Cebrian (1996), Upadhyaya and Singh (2001), Kadilar and Cingi (2006 a,b), Shabbir (2006), Singh et al. (2014) estimator and subfamilies of estimators of Shabbir and Gupta (2006), Singh and Solanki (2013 a,b), Singh et al. (2014) and Singh and Pal (2016) theoretically as well as numerically. An empirical study is carried out to show the performance of the proposed estimator over the usual unbiased estimator s_y^2 and some recent estimators and subfamilies of estimators.

Keywords: *Study variable, auxiliary variable, bias, mean squared error and simple random sampling.*

Resampling Techniques of Variance Estimation in Two-Stage Sampling under Dual-Frame Surveys at the PSU Level

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Abstract

The Multiple Frame (MF) Survey is an innovative approach that combines two or more sampling frames, departing from the conventional use of a single frame for units in the target population. The principal objective of deploying MF surveys lies in the strategic reduction of costs while concurrently upholding estimation efficiency, nearly commensurate with single frame survey methodologies. In many cases, a frame that covers the entire population is very expensive to sample from. So, an alternate frame may be available that does not cover the entire population but it is cheaper to sample from. For multi-stage designs, the theory of multiple frame surveys (Hartley, 1962, 1974) becomes somewhat complicated as the alternatives for multiple frame approach multiply. For example, in two-stage sampling there may be multiple frames at the first stage and single frame at the second stage or vice-versa. There may be situations where more than one frames are available at each stage of selection. Here, we have considered the case where dual frames are available at Primary Stage Unit (PSU) level. Saxena et al. (1984) extended Hartley's estimator for two stages sampling when domain size is known considering cost factor. Hartley (1962) observed that obtaining unbiased variance estimation for various population parameters is challenging and complex in the case of multiple frame surveys compared to single frame sampling. Unbiased variance estimator is very tedious to obtain for estimator using multiple frames as the estimator is non-linear and complex in nature. Therefore, alternatively we can use resampling methods of variance estimation e.g. resampling technique developed by Ahmad (1997) in case of multiple frame surveys under two stage sampling design for known domain size case.

To address these challenges, Kumar et al. (2021) proposed rescaled unbiased variance estimation procedures for simple random sampling under dual frame surveys. In this study we have developed different rescaled unbiased variance estimation procedures for estimating variance unbiasedly for two stage sampling under dual frame surveys at PSU level namely, (i) Stratified Rescaling Two Stage Bootstrap with Known

Domain size and (ii) Post-stratified Rescaling Two Stage Bootstrap with Known Domain size. Furthermore, to assess the performance of the developed procedures in comparison to the standard existing procedures without considering rescaling factors, a simulation study is conducted. The performances of the developed resampling techniques are evaluated based on calculating Percentage Relative Bias (RB) and Relative Stability (RS). This comprehensive exploration aims to provide insights into the effectiveness of the proposed bootstrap variance estimation techniques in the context of Multiple Frame Surveys.

Keywords: *Multiple-Frame Survey, Dual-frame, Domain, Multi-stage designs, PSU, Resampling methods, RB, RS.*

Abiotic Stress Mapping using Spatially Integrated AHP-RF Approach Coupled with CLHS-based Validation

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Abstract

Abiotic stress refers to non-living environmental factors (temperature extremes, drought, excessive rainfall, soil salinity, nutrient deficiencies, soil erosion) or external conditions that adversely affect the growth, development, and overall productivity of crops. Accurately mapping abiotic stresses is crucial for agricultural planning and resource management. This study presents a novel approach for abiotic stress mapping by integrating the Analytical Hierarchy Process (AHP) and Random Forest (RF) model with strategically chosen Conditioned Latin Hypercube Sampling (CLHS) points for robust validation. An abiotic stress index (ASI) for Pune district, India, has been generated by combining various terrain, climatic, pedological and vegetation parameters using an AHP combined RF model. Integration of these thematic layers was performed using a weighted sum approach to generate an abiotic stress map. To ensure robust validation, a CLHS sampling strategy has been implemented for generating spatially balanced and representative training points across the diverse stress levels observed in the region. A receiver operating characteristic (ROC) curve has been generated using these selected points to confirm the model's ability to effectively discriminate between

different stress levels. Furthermore, validation through Google Earth imagery indicates good agreement with the model output. This spatially integrated AHP-RF model, coupled with CLHS validation, provides a reliable and efficient approach for generating accurate abiotic stress maps, ultimately enabling informed decision-making for sustainable agricultural practices.

Keywords: *Abiotic stress; Analytical Hierarchy Process; CLHS; Random Forest; ROC*

Assessing Precision in Dairy Research: A Case Study of Systematic Sampling Methods for Surati Buffalo Milk Yield

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Abstract

India, the world's leading milk-producing country, reported a 3.83% increase in milk production during 2022–23 compared to the previous year, with the top five states contributing 53.08% to the total production. Gujarat ranked fourth, contributing 7.49% to the overall milk production. Livestock farming plays a vital economic and cultural role in rural communities, serving as an indirect form of insurance against crop failure resulting from natural calamities such as droughts and floods. This study utilized the daily milk yield data (DMYD) of three Surati buffaloes, which were collected from the Livestock Research Station, N.A.U., Navsari, for one lactation period over a period of 2015 to 2020. An analysis was undertaken to compare three sampling methods: simple random sampling, typical systematic sampling, and modified systematic sampling. The average variance was calculated for these datasets, revealing that typical systematic sampling demonstrated the least variance among the three methods. Consequently, the study concludes that the typical systematic sampling method is more accurate than both simple random sampling and the modified sampling method

Keyword: *Surati buffalo, Simple random sampling, Systematic sampling, Modifies systematic sampling*

An insight of agricultural accidents in Indore District of MP

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Abstract

Inadvertent neglect of ergonomical aspects in design and operation of various tools & machinery lead to many casualties and injuries due to accidents while modernizing farm mechanization to carry out different agricultural activities. To quantify the gravity and economic loss of these accidents, a study was carried at Indore district. Snowball sampling was used for collecting data on agricultural accidents in 20 villages using mobile app. The data was analysed machine-wise, severity, nature, cause, age, gender and educational of victims. The analysis indicated that the estimates of agricultural accidents in Indore are of serious concern. Farm machinery related accidents were 28 % fatal and 72 % non-fatal. Accidents due to hand tools are of non-fatal nature. It is estimated that about 11,191 agricultural accidents occur in in a year in Indore district. Total monetary loss estimated due to agricultural accidents in this district was Rs. 212.82 crore/yr. The major contributors to the accidents are tractors (21%), threshers (21%), Electric motors (11%) and chaff cutters (5%). Education, training and awareness should play a major role as most of the accidents are due to ignorance, lack of skill, protective gadgets and safety. About 79% of the accidents are due to poor education. Majority of accidents occurred within the age group of 30-40 yrs. The study concludes that education, training, awareness and adopting standard components while using machinery at village level will minimize the accidents effectively.

Keywords: *Agricultural accidents, farm mechanization, estimation, Snowball sampling.*

Yardstick of CV% for mango crop experiments

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Abstract

Large number of field experiments with various objectives were conducted on Mango (Mangifera indica L.) at different locations. It is the most important commercially grown fruit crop of the country. South Gujarat is dominant region of mango in terms of area and production. This study was carried out to develop the yard stick of CV% for accepting the results of mango crop experiment utilizing the secondary data on yield of 158 field experiments conducted at various research stations of South Gujarat region of last 15 years. The yardstick of CV for field experiments was worked out by using average upper fiducial limit of CV for each of the 158 experiments were worked out separately and then average of these upper fiducial limits was computed. The upper fiducial limit of 95% and 99% worked out by using the theory of truncated t-distribution as described by Johnson and Welch, 1939. The results implied that most of the experiments were conducted in single factor Randomized Block Design. Number of treatments between 6-10 showed lower CV% as compared to overall average CV%. The experiments conducted with 3, 4 and 5 replications provide lower CV%. The experiments conducted at RHRS, Navsari had less CV% as compared to AES, Paria. Higher CV% in experiments reduces the power of F-test. The yardstick of CV% for accepting the results of mango experiments in South Gujarat region should be less than 29 per cent for yield character.
Keywords: *Coefficient of variation, yardstick, mango, fiducial limit.*

Yield estimation of Sapota using different sampling techniques

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Abstract

Horticultural crop plays a unique role in India’s economy, therefore reliable and timely estimates of the yield of horticultural crops are of vital importance. Sapota (Manilkara zapota) commonly known as chicoo, is a commercially well-known fruit cultivated in various regions of India. The production of sapota is about 834.08 thousand tonnes (NHB,2021-22) in India and the leading sapota producing state is Gujarat with

273.87 thousand tonnes production (NHB,2021-22). Estimation of sapota yield is essential for efficient agriculture management, resource allocation, and market forecasting. Sampling is one of the important methods that determines the correctness of survey results. Probability sampling allows the investigator to generalize the findings of the sample to the target population which includes Simple random sampling, Systematic random sampling, stratified random sampling, Cluster sampling, etc. Sampling techniques are employed for yield estimation in agriculture to gather representative data without the need to assess the entire production. These approaches are cost-effective and efficient, especially when dealing with large areas. By carefully selecting and analyzing samples, one can make reliable predictions about the overall yield. It provides a practical way to monitor and manage production without the time and resource demands of assessing every unit. Additionally, sampling helps to identify variability and trends within the production system, contributing to better decision-making and resource allocation.
Keywords: *Sapota, Yield estimation, Sampling techniques*

Sustainable Carbon Storage Potential in Trees for Mitigating Climate Change

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Abstract

Climate change is the most challenging task and it mainly caused due to green-house gases (GHGs), especially CO2, which represents 77% of total GHG emissions. Further, human activities, especially the burning of fossil fuels have caused a substantial increase in the concentration of carbon dioxide (CO2) in the atmosphere. Therefore, its mitigation is very much essential in current situation. Here, forest plays an important and crucial role in mitigating climate change through carbon sequestration by storing carbon in different parts of the tree/plant, especially in the wood. Tree plantations find a place for environmental sustainability in terms of managing micro climate, carbon sequestration, etc. Efforts have been made to identify suitable forest species that sequester more CO2 within short period of time. In the present study, we worked out carbon storage potential of Albizia procera using ten different girth classes viz., G1: 10-25 cm, G2: 25-40 cm, G3: 40-55 cm, G4: 55 -70 cm, G5: 70-85 cm, G6: 85-100 cm, G7: 100-125 cm, G8: 125-150 cm, G9: 150-175 cm and G10: 175-200 cm using different plantations and naturally scattered trees in the Navsari district of Gujarat. Study shows that there was a significant increase in carbon storage from lower girth classes to higher

girth classes in A. procera. An average carbon content per tree was about 7 kg and 15 kg in lower girth classes of G1 and G2, respectively to 509 (G9) and 689 kg tree-1 in higher girth classes of G9 and G10, respectively. Study concludes that A. procera could be one of the suitable tree species for climate change mitigation through tree plantation; further, the information provided here would help in assess the carbon storage of individual A. procera tree on standing condition.

Keywords: *Albizia procera, Climate change, Carbon storage*

Population Dynamics of Sapota Seed Borer (*Trymalitis margarias Meyrick*) and their correlation matrix with weather variables

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Abstract

Seed borer, Trymalitis margarias Meyrick is an emerging pest in sapota orchards of the Konkan region. An investigation on the seasonal incidence of sapota seed borer (T. margarias) was carried out during two successive years 2020 and 2021. In 2020, seed borer seasonal occurrence patterns indicated that the incidence commenced in September and the peak activity was recorded during November-December (5.25 to 7.05 larva) and January (7.6 to 12.65) at the fruiting phase. The minimum seed borer population was noticed during June-July (1.6 and 2.6 larvae). In 2021, seed borer peak activity was recorded during November-December (5.25 to 7.05 larva) and January (9.35 to 10.6 larvae) at the fruiting phase. The minimum seed borer population was noticed during June-July (0.6 and 1.0 larvae). Correlation studies for both years revealed a highly significant negative correlation between seed borer incidence and Rainfall, Temperature (min), and RH (Morning and Evening), while Temperature (max) showed a positively non-significant correlation. The analysis emphasized the prevailing negative impact of minimum temperature, evening relative humidity and rainfall during the peak infestation period on seed borer-induced fruit damage. This information contributes to the understanding of the sapota seed borer's seasonal dynamics and its correlation with

environmental factors, offering insights for effective pest management strategies in sapota orchards of Konkan region.

Keywords: *Sapota, Seed borer, Trymalitis margaritas, Population dynamics, Correlation*

Population Dynamics of Spotted Pod Borer, Maruca vitrata (Fabricius) in Relation to Weather Parameter in Greengram

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Abstract

An experiment on the population dynamics of spotted pod borer, *Maruca vitrata* (Fabricius) (Lepidoptera: Crambidae) in greengram was conducted at Anand Agricultural University, Anand, Gujarat during kharif 2021. The incidence of spotted pod borer commenced in the third week of August [34th Standard Meteorological Week (SMW)] and it continued up to the harvest of the crop in the 42nd SMW. The spotted pod borer population fluctuated between 0.48 to 2.45 larva(e)/plant with a peak population during the third week of September (38th SMW). A higher incidence of spotted pod borer was observed during the 37th to 42nd SMW. The larval population of M. vitrata exhibited a significant positive correlation with bright sunshine hours (r = 0.7336) and significant negative correlation with the wind speed (r = -0.7006).

Keyword: *Greengram, spotted pod borer, Maruca vitrata, Weather*

Rescaling bootstrap variance estimation of the prediction-based estimator under two-phase sampling

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Abstract

Two-phase sampling is commonly used in large-scale surveys when it is very expensive to collect data on the variables of interest but comparatively inexpensive to collect data on variables that are correlated with the variables of interest. In sample surveys, the prediction technique is used to predict the non-sampled units based on auxiliary variables then it is used to create estimators of population parameters. Recently, an estimator of the finite population total has been proposed by Varshney et al. [20] which was a prediction-based estimator under two-phase sampling. However, they have not discussed sampling variance and its estimator. It can be seen that the proposed estimator is non-linear in nature. So, for the proposed estimator under two-phase sampling, the bootstrap variance estimation technique has been developed in this article. According to the simulation study, it has been seen that the proposed bootstrap method provides an unbiased estimator of the variance of the prediction-based estimator.

Keywords: *Two-phase sampling, prediction approach, variance estimation, resampling techniques, rescaling factor, simulation*

A Novel Survey-Weighted Propensity Score Methodology to Enhance Impact Assessment

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Abstract

This paper introduces a novel methodology for propensity score analysis (PSA) tailored to incorporate survey weights from complex survey data, addressing a critical gap in current research practices. Propensity score methods, notably propensity score matching (PSM), are commonly utilized for estimating treatment effects in non-randomized scenarios where random assignment is unfeasible. In the context of complex survey designs, the inclusion of survey weights is essential for producing results that accurately represent the target population. Neglecting these weights may lead to biased estimates at the population level. The developed statistic has been illustrated with a real-

life data set. It is observed through analysis that ignoring the survey weights affects the estimate of the population parameter.
Keywords: *Treatment effects, propensity scores, complex surveys, sampling weights.*

Application of Sampling Techniques in Agriculture

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Abstract
In order to answer the research questions, it is doubtful that researcher should be able to collect data from all cases. Thus, there is a need to select a sample. Furthermore, as there are different types of sampling techniques/methods, researcher needs to understand the differences to select the proper sampling method for the research. Researchers donot study the entire population for two reasons the cost is too high, more time require to draw the conclusions and the population is dynamic in that the individuals making up the population may change over time. The three main advantages of sampling are that the cost is lower, data collection is faster, and since the data set is smaller it is possible to ensure homogeneity and to improve the accuracy and quality of the data. Sampling is an important aspect of data collection. To an observer of developments in sampling over the last 25 years the most striking feature is the rapid increase in the number and types of surveys taken by sampling. The Statistical Office of the United Nations publishes reports from time to time on "Sample Surveys of Current Interest" conducted by member countries. The 1968 report lists surveys from 46 countries. Many of these surveys seek information of obvious importance to national planning on topics such as agricul- tural production and land use, unemployment and the size of the labor force, industrial production, wholesale and retail prices, health status of the people, and family incomes and expenditures.
Keywords: *Sampling techniques, Survey methodology, Data collection*

TS 4: Forewarning and Forecasting Modelling for Crop Production and Health Monitoring

INVITED TALK

Evaluating small scale fisheries: models, dimensions and data requirements

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Statistical and econometric models are extensively used to evaluate fisheries for examining sustainability and suggest suitable policies for management. Technology induced changes in the fisheries sector have shown continuous and sustained increments in fish production in the country. Increased fish production from the marine sector was driven primarily by the introduction of steel trawlers, apart from the technological innovations in fishing gear which together have helped the fishermen to increase their area of operation and make fishing more economical (Ravi et al., 2014). The total fish landings increased from a meagre 7.52 lakh MT in 1951-52 to 6.2 million MT in 2009-10 and presently fish production is put at 17.54 million MT. To identify the drivers and barriers in production and trade, the time series data sets are often subjected to trend analysis. The time series model due to Bai and Perron (2003) was used to study the multiple structural breaks that can relate to the technology changes or policy interventions in the sector.

$$y_t = x_t' \beta + z_t' \delta_j + u_t t = T_{j-1} + 1, \dots \dots \dots .., T_j \quad (1), \; j=1,\dots, m+1$$

where y_t is the observed dependent variable at time $t; x_t(p \times 1)$ and $z_t(q \times 1)$ are vectors of covariates and $\beta \; and \; \delta_j (j = 1, \dots, m + 1)$ are the corresponding vectors of coefficients; u_t is the disturbance at time t. The breakpoints $(T_{1,\dots,}T_m)$, are explicitly treated as unknown (we use the convention that $T_0 = 0$ and $T_{m+1} = T$). The model could capture the structural breaks in long-run fish production and exports, which point toward the policy interventions that happened in the sector. The model consists of multiple linear regression models at time t for each segment of breakpoint and the breakpoints Tj which are unknowns are estimated using the time series data. The Granger causality study has demonstrated a bidirectional causal relationship between marine product production and export.

The large fishing capacity established in the fishing sector coupled with stakeholder-led innovations to thwart low returns has led to non-optimal exploitation of fishery resources requiring appropriate management interventions. Estimating fishing capacity in the Indian fishing fleet to study resource sustainability can be accomplished using data envelopment analysis (Kirkley and Squares, 1999). Capacity in fisheries is the difference between the maximum potential output – given technology, current resource conditions, full and efficient utilization of capital stock, other fixed and variable factors and the observed output. Any assumption on the economic behavior of fishermen (eg. Minimizing cost) leads to the concept of economic efficiency which is composed of technical and allocative efficiency. Fishery managers may reduce technical efficiency by constraining the use of certain inputs or they may improve it by expanding the inputs or by taking measures that properly define the property rights of the fishery. Evaluation of the capacity utilization reveals the observed best-practice frontier established by the existing fleet and implicitly reflects economic decisions made by vessel operators (Vestergaard et al., 2002). Cross-section, time series, or panel data of the fishery for which fishing capacity is to be estimated are used to fit these models. A comprehensive assessment of the dimensions, hardware components, and vessel operating behavior of India's existing mechanized fishing fleet points out huge variability in dimensions, installed power, fishing type (gear), propulsion, and design of fishing crafts. Sufficient data on the fishing operations carried out in a fishery during continuous periods of time is crucial as also the representativeness of the units. Even though, on the whole, the dimensions and power of fishing units in mechanized sector has increased, there is wide variation in the population. For example, 41% of steel trawlers in Ernakulam are fitted with engines in the range 100-200Hp, 26% with engines of 200-300 HP range, 17% with engines of 300-400 HP range and 16% with engines above 400 HP. 44% of the vessels are below 20 m whereas 56% are above 20 m in length. Whereas in Kollam, 67% of the vessels are in the 15-20 m range and 11% are above 20 m. Therefore before employing the statistical models to assess fishing capacity in a particular fishery, representative units of all categories have to be covered while recording the data. Sufficient data on the fishing operations carried out in a fishery during the time continuum is crucial as also the representativeness of the units as the wide variation among units have to be taken into account during sampling.

Culture-based fisheries in reservoirs is a successful aquaculture practice in vogue in many parts of the world and also in India for enhancement of fish production. Mathematical models are extensively used in the study of small-scale fisheries practiced in the lakes and reservoirs. Starting from Von Bertlanffy's growth model for fish growth, many models have been developed for the prediction and management of small-scale fisheries in lakes and reservoirs (Von Bertalanffy1938). Population dynamics of stocked fishes in the reservoirs were studied using density-dependent growth models (Lorenzen, 1996, Lorenzen et al., 1997) which offer a sound framework for adopting management measures for production enhancement.

Lorenzen (1996) expressed asymptotic length as a linear decreasing function of population biomass density (Biomass per unit area or volume) as

$$L_{\infty B} = L_{\infty L} - gB$$

where $L_{\infty \cdot B}$ is asymptotic length at biomass B, is limiting asymptotic length $L_{\infty L}$ of the growth curve in the absence of competition and g is the competition coefficient.

The main technology management problem here lies in the identification of optimum stocking and harvesting regimes that can enhance production while ensuring the sustainability of fisheries. The mortality and growth of the stocked fish depend on the natural conditions of the reservoir and the competitiveness for food among the stocked fish is also taken care of by these models. Density−dependent growth models applied to time series data on the length−weight of stocked fishes can be used to evaluate various management regimes involving the stocking of major carps in small reservoirs which have greater scope for fishery enhancement in the country. Density dependent growth models due to Lorenzen(1996) was applied to timeseries data on length weight of major carps stocked at Kanzirapuzha reservoir at Palakkad and various management options were explored (Geethalakshmi et al., 2019).

Compared to the national average, the annual productivity of many small reservoirs is very low. What is notable for high productivity reservoirs is that there have been interventions from the State and other actors who regularly undertake and implement schemes to maintain the production. Often despite conducive natural conditions for growth in the reservoir and regular stocking, the fishing effort may be non−optimal. Surplus production models are widely used to estimate Maximum Sustainable Yield (MSY) and optimum efforts to obtain the MSY. An integrated surplus production model (Clarke et al., 1972) was used to evaluate fishery in tropical reservoirs which could be further used for prediction and evaluation of management options (Geethalakshmi et al, 2020).

This paper presents the various statistical models that have been applied to fisheries data to evaluate small-scale fisheries based on case studies, outlining the limitations and data considerations. The paper has been organized as follows – outline of the models /methods available for evaluating fisheries, models for measuring fishing capacity and the data considerations, density-dependent growth models and integrated surplus production models for managing stocking-based fishery, and presentation of empirical illustrations.

Keywords: *surplus production models, structural breaks, fishing capacity, econometric evaluation, density dependent growth*

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Enhancing Prediction Accuracy by Wavelet based Denoising Approach

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Denoising is an integral part of the data pre-processing technique that often works in conjunction with model development for enhancing the quality of data, improving model accuracy, preventing over fitting, and contributing to the overall robustness of predictive models. Algorithms based on combination of wavelet with deep learning, machine learning and stochastic model have been proposed. The denoised series are fitted with various benchmark models, including Long Short Term Memory (LSTM), Support Vector Regression (SVR), Artificial Neural Network (ANN) and Autoregressive Integrated Moving Average (ARIMA) model. In the current study, the effect of wavelet based denoising has been illustrated on the monthly wholesale prices of three pivotal spices—Turmeric, Coriander, and Cumin collected from the diverse markets across India. The wavelet denoising involves the application of methods or algorithms to filter out the extraneous noise, enabling the model to focus on the relevant patterns and relationships in the data. The various levels of decomposition has been taken into account for studying the effectiveness of denoising. The benchmark modeling phase commenced with the deployment of the ARIMA model, a widely recognized time series forecasting method. The modeling spectrum expanded to include ANN, SVR, and LSTM models. These models were subjected to hyperparameter optimization through a grid search method, aiming to fine-tune the parameters for optimal performance. The predictive performance of the models is assessed using Root Mean Square Error (RMSE), Mean Absolute Percentage Error (MAPE) and Mean Absolute Error (MAE). The results on the test set unequivocally indicated the consistent superiority of LSTM across all three spices, showcasing its adeptness in capturing the intricate patterns inherent in the data. The performance of each model may vary with different decomposition levels, emphasizing the importance of carefully selecting the appropriate level based on specific modeling objectives and metric priorities. The comparative analysis between the wavelet-based denoising models (WLSTM, WSVR, WANN, and WARIMA) and their traditional counterparts provided resounding affirmation regarding the substantial enhancement in predictive accuracy introduced by wavelet transforms. Across all three spices, denoising consistently led to significant reductions in error metrics, with percentage decreases ranging from 30% to over 40%. The results clearly highlighted the superiority of wavelet based denoising approach in enhancing the accuracy of price forecasting.

Keywords: *Denoising; Price Forecasting; Machine Learning; LSTM; Wavelet Decomposition*

Machine Learning Vs Statistical Models: Predicting Horticultural Commodity Prices

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Forecasting prices of horticultural commodities like banana carries significant implications for a diverse group of stakeholders, including farmers, traders and consumers as banana stands for the world's seventh most traded agricultural product. India, leading in global banana production, contributes with 30.5 million tonnes,

followed by China (12.0 million tonnes), Indonesia (7.2 million tonnes), Brazil (6.8 million tonnes) and Ecuador (6.6 million tonnes), highlighting India's substantial contribution to the global banana market countries. In 2019, the country’s production, surpassing any other nation and accounting for approximately 26% of the global supply (FAOSTAT 2020). In 2020, within India, Gujarat was the second-highest producer of bananas, following Tamil Nadu. Among the top five banana-producing states in the country, Gujarat held a significant 24% share of the total output (National Horticulture Board 2020).

The notable fluctuations in the pricing of these commodities provide farmers with opportunities to maximize profits by strategically navigating different local markets. While machine learning models have shown promising results as effective alternatives to traditional statistical methods, their widespread adoption for price prediction in the Indian horticultural sector is still an unexplored subject. Historically, the prediction of agricultural commodity prices has depended on a variety of statistical models, each bearing its own unique set of challenges and limitations. This reliance on variety of models reflects the complexity and variability inherent in agricultural markets, making accurate price forecasting a challenging yet crucial task.

Machine learning models have significantly emerged as powerful alternatives to traditional statistical methods in forecasting. In our study, we focused on evaluating and contrasting the effectiveness of various statistical and machine learning models to attain precise forecasts for agricultural prices. This investigation included a comprehensive application of models like the Autoregressive Integrated Moving Average (ARIMA), Seasonal ARIMA (SARIMA), Autoregressive Conditional Heteroscedasticity (ARCH), Generalized ARCH (GARCH), Time Delay Neural Network (TDNN) and Recurrent Neural Network (RNN). Following are the model:

S/ARIMA (Seasonal/Auto Regressive Integrated Moving Average model): S/ARIMA models are used for forecasting time series data. They combine differencing with auto-regression and a moving average model to capture various aspects of the time series, making them particularly effective for short-term forecasting. It incorporates seasonal if there is seasonal pattern existing the dataset.

$$y_t = \emptyset_1 y_{t-1} + \emptyset_2 y_{t-2} + \ldots + \emptyset_p y_{t-p} + \varepsilon_t - \emptyset_1 \varepsilon_{t-1} - \emptyset_2 \varepsilon_{t-2} \ldots - \emptyset_p \varepsilon_{t-q} \ldots (1)$$

where, y_t is the actual value at t, $\{\varepsilon_t\}$ is the white noise sequence, p and q are integers which are called autoregressive and moving average, respectively.

G/ARCH (Autoregressive Conditional Heteroscedasticity model): ARCH models focus on modeling the conditional variance (volatility) of a time series, making them useful in scenarios where data shows periods of increasing or decreasing volatility. An extension of the ARCH model, GARCH captures both short and long-term effects in volatility.

If the disturbance term is Yt sequence, et has a conditional variance of σ_t^2.Then for GARCH model (p, q) by Bera, A. K. & Higgins, M. L. (1993) :

$$\sigma_t^2 = \alpha_\circ + \alpha_1 e_{t-q}^2 + \cdots + \alpha_q e_{t-q}^2 + \beta_1 \sigma_{t-1}^2 + \cdots + \beta_p \sigma_{t-p}^2 \quad \ldots\ldots\ldots (2)$$

Where the inequality restrictions, α° term is the constant in the model, which represents the long-run average of the conditional variance $\alpha_i \geq 0$ for i = 1,….,q and $\beta_i \geq 0$ for i = 1,….,p are imposed to guarantee that the conditional variance is non-negative.

Time Delay Neural Network (TDNN): TDNNs are advanced machine learning models that mimic the neural structure of the human brain. They excel in identifying complex, nonlinear relationships within data, adapting and learning from the data they process mathematical expression of model is:

$$y_t = a_\circ + \sum_{j=1}^{q} a_j g\left(\beta_{\circ j} + \sum_{i=1}^{p} \beta_{ij} y_{t-i}\, n\right) + \varepsilon_t, \quad \ldots\ldots\ldots (3)$$

Here $y\ t$ −i (i = 1, 2, ... , p) are the p inputs and yt is the output.

RNN (Recurrent Neural Network): RNNs are a class of neural networks designed for sequential data, capable of learning from previous inputs in a sequence. This 'memory' aspect makes them ideal for time series forecasting and other applications where the context or order of data points is important. The equation of RNN can be expressed as:

$$h_t = f(W_{xh} X_t + W_{hh} H_{t-1} \ldots\ldots\ldots (4)$$

$$O_t = f(W_{xo} S_t) \ldots\ldots\ldots (5)$$

X_t is input at time t, $H_{t-1}$is state at time t-1, $W_{xh}, W_{hh}\ and\ W_{xo}$ are weight matrices for input, hidden and output layers.

These models, when applied to the dataset of banana prices in Gujarat, India, were assessed using metrics such as RMSE (Root Mean Square Error), MAPE (Mean Absolute Percentage Error), MASE (Mean Absolute Scaled Error), SMAPE (Symmetric Mean Absolute Percentage Error), and MAD (Mean Absolute Deviation) to validate their predictive capabilities.

Building on our goal to identify the most effective methods for price prediction, while considering the dynamic market trends and the potential of advanced data analysis in the Indian agricultural sector, our investigation focused on forecasting banana prices in Gujarat. The investigation revealed that the Recurrent Neural Network (RNN) model surpassed competing models in crucial metrics like RMSE, MAPE, SMAPE, MASE and MAD. This outcome emphasizes the RNN's utility in facilitating decision-making for both policymakers and farmers, potentially invaluable for farmers, traders, and end-users, offering a solid basis for making more informed decisions about pricing and trading. However, it should be noted that our research had limitations, such as not incorporating factors like weather conditions, market demand and supply and government policies.

Keywords: *Machine learning models, Statistical models, Price forecasting*

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Arbitrage of Forecasting Experts Based Hybrid Time Series Model for Crop Yield Prediction

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Forecasting holds significant importance across various domains. In field of forecasting, time series models designed to account for temporal dependencies among observations. However, it is widely acknowledged that no single model is universally applicable. To address this challenge, a common approach involves aggregating forecasts from a diverse set of models. In this paper an approach based on arbitrating, in which several forecasting models are dynamically combined to obtain predictions, has been

introduced. Arbitrating approach for retrieving out-of-bag predictions that significantly improves its data efficiency. This research introduced a novel hybrid time series based on arbitrage of forecasting experts for crop yield prediction. The performance of the proposed algorithm is evaluated using various accuracy metrics. Empirical illustration showed that our proposed algorithm demonstrates superior performance compared to traditional models.

Keywords*: Combining expert advice, Dynamic ensemble, Meta-learning, Time series.*

Statistical Modelling for Prediction and Validation of Sheath Mite (*Steneotarsonemus spinki*) Population Dynamics in Rice

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Rice, essential for half the world daily, dominates as the primary crop of global dietary and vital for the poor in Asia and Africa who lack access to nutritious foods, stands as a strategic global commodity, integral to food security, economic growth, and regional stability. Rice is serving as a staple food for 800 million people, influencing diet, economy, and culture. The panicle rice mite (PRM) or rice sheath mite (RSM) - Steneotarsonemus spinki - is recognized as a significant global threat to rice crop. it has been infesting rice fields since the 1970s, causing extensive damage. Associated with sterility, partial panicle infertility, and grain deformity, S. spinkis impact is challenging to isolate due to concurrent plant pathogen presence. In recent years, it has emerged as a severe non-insect pest in Gujarat, particularly affecting south Gujarat conditions. As the insect growth is not simply rapid; rather, insects follow a qualitatively distinct trajectory to many other animals. It is well recognized that any type of statistical inquiry in which principles from some body of knowledge enter seriously into the analysis is likely to lead to a Nonlinear model.

Growth models are mechanistic in nature, rather than empirical. The utility of such models is that, on one hand, they help us to gain insight into the underlying mechanism of the system and on the other hand, they are of immense help in efficient management. Six realistic non-linear growth models viz., Prejneshu, Logistic, Monomolecular, Gompertz, Exponential and Sinusoidal have been used in the current investigation. The study was carried out using the data of sheath mite population of 18 mereological weeks of 10 years from 2011 to 2020.

The maximum SMP was observed across all the year in 43rd SMW (2-3 weeks of October). It is also noteworthy that the rice cultivar in Navsari, the SMP becomes vulnerable from 38th to 46th SMW across all the study year. Looking at the overall period, the 42nd and 43rd SMW were showed the highest mean population i.e., 7.45 and 7.34, respectively. Although, the year 2012 also witnessed an abnormal population as compared to remaining years due to favourable environment for rice mite's growth.

The weather parameters viz., maximum temperature (MAX T), minimum temperature (MIN T), maximum relative humidity (RH 1), and minimum relative humidity (RH 2) has been influenced profoundly on the occurrence of sheath mite. From the correlation study, it was clearly observed that the occurrence of the mite population highly correlated with the host phenology and the prevailing weather parameter. MAX T and RH 1 influenced mite population in greater extent across all the years. Also, the highly positive and negative significant correlation was observed for the sheath mite population in relation to MAX T followed by RH 2. The heat map is used to visualize the correlation study which was carried out. The mite populations grow tremendously at high temperature and high humidity during last fortnight of September and sometimes continue to 1st fortnight of October which was observed to be the common weather pattern during all the years in the Navsari. The weather situation discussed above favours to build up profuse mite colonization that synchronize with the panicle emergence stage of the short and medium durational rice cultivars and hence, is the reason to cause severe yield loss due to sheath mite infestation. PCA analysis was also carried out in order to derive the conclusion about the association among various years. Biplot of PCA analysis which shows that the years 2012 and 2014 have similar data and correlated positively. 2017 and 2021 also are highly correlated where as these two are moderately correlated with the years 2011, 2013, 2015, 2016, 2018, 2019, 2020 which are highly correlated among themselves. Scree plot showed that almost 98% of the variation in the population over the years are explained by PC1, PC2 and PC3 together.

Before Forecasting of Sheath mite population dynamics using non-linear models the independence of residuals was checked by using run test. The normality of the residuals was examined by using the Shapiro-Wilk test. The R2 statistic indicates the percentage of the variance in the dependent variable that the independent variables explain collectively. R-squared measures the strength of the relationship between the model and the dependent variable. Similarly, low value of RMSE (Root mean square error) is best indicator of precision of your experiment in term of low difference between the observed and expected value of sheath mite population. On the basis of R2 and RMSE, it was observed that in a different year, different models showed varying patterns of their fitting but most of the variation are explained by Monomolecular (M3) fitted model and Sinusoidal (M6) fitted model correctly. The best fitting of the model was showed by Sinusoidal (M6) fitted model, Monomolecular (M3) fitted model, Gompertz (M4) fitted model and Logistic (M2) fitted model respective in different years on the basis of frequency. The Sinusoidal model exhibited best in most of the year as compared rest model for study periods. Coming to the overall period i.e. 2011 to 2020 period, the Sinusoidal model again preform best in contrast to the remaining model as exhibiting highest R2. In order to validate the proposed model for sheath mite population in rice in this region model validation has been carried out with data belonging to the year 2021. On the basis of RMSE and coefficient of determination R2, we can say proposed sinusoidal model which clearly describes 94.21 per cent variation in the sheath's mite population for the overall period and found best-validated one with the year 2021 as compared to others.

As a conclusion it can be said that the highest population (14.37 mites cm-2) of mite observed at the ripening stage of the rice crop. The mite population grows tremendously at high temperatures and high humidity during the last fortnight of September and the first week of October. A total of six nonlinear models has been compared for each year 2011 to 2020 including the overall period, and it can be concluded that the sinusoidal model utilized in the study over the years described well the behaviour of sheath mite population growth in rice crop for Navsari, Gujarat. This model can be utilized for the study of sheath mite population growth dynamics in an area where climate resembles the Navsari, Gujarat.

ABSTRACT

Forecasting Agricultural Price Volatility using GARCH-MIDAS Model for Onion Crop

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Abstract

Agricultural commodity prices exhibit heightened volatility primarily attributed to factors such as seasonality, inelastic demand, and various other influencing elements. The escalation in price volatility signifies an elevated level of uncertainty regarding forthcoming prices, a phenomenon with potential repercussions on the well-being of

producers. Price volatility serves as a metric gauging the potential fluctuation or shifts in the price variable, presenting a dynamic landscape for market participants and contributing to increased unpredictability in the agricultural sector.

The widely adopted non-linear GARCH model lacked the ability to include explanatory variables in conditional variance. Recently, attention has turned to multiple component models to overcome this limitation. Specifically, the class of generalized autoregressive conditional heteroscedasticity mixed-data sampling (GARCH-MIDAS) models has demonstrated its efficacy in examining the nexus between financial volatility and the macroeconomic environment. Within the GARCH-MIDAS framework, a unit-variance GARCH component undergoes fluctuations around a time-varying long-term component, which is contingent upon explanatory variables. By accommodating a mixed-frequency setting, this methodology bridges the gap between daily volatility and low-frequency explanatory variables. Consequently, this study endeavors to construct a pertinent GARCH-MIDAS model tailored for forecasting the volatility of Onion crops by discerning and incorporating key explanatory variables. Where the real-life data has been taken from website: https://agmarknet.gov.in for the year 2015 to 2020.

Keywords: *GARCH model, GARCH-MIDAS model, Maximum Likelihood Estimation*

Hectareage Prediction Models for Kharif Groundnut Crop in Amreli District, Gujarat

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Abstract

The present study was conducted in order to identify the models for predicting crop hectareage of kharif groundnut crop in the Amreli district of Gujarat state. The investigation was carried out on the basis of secondary data covering the period of 21 years (2000-01 to 2020-21). The linear multiple regression technique adopting Nerlovian adjustment model was employed. Eight single equation and four simultaneous equation models were tried for the selected crop. The model selected based on the values of coefficient of multiple determination (0.943), adjusted coefficient of multiple determination (0.904), RMSE (194.73), MAE (158.52) and MAPE (10.29) values is as

HEGN= -145.699+0.232HEGNL1+2.209**HESM-0.327*HEUCT +0.318*EYGN +2095.021REPGN +0.826*RFJ -0.271 PRSK-0.395*YRSK which is a single equation model.

Keywords: *Hectareage, kharif groundnut, Nerlovian adjustment model, Single equation model, Simultaneous equation model, Adjusted coefficient of determination, RMSE, MAE, MAPE*

Impact of Environmental Factors on Pest Population Using Multivariate Cointegration Model: Evidence from India

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Abstract

One of the main challenges in achieving higher productivity of crop are the prevalence of various insect pests and diseases. These pests are highly sensitive to extreme weather conditions, and the interaction between weather patterns and pest infestations significantly affects crop yield. Traditional statistical methods struggle to capture the complex temporal and geographical dynamics of these interactions. However, employing multivariate cointegration proved valuable for estimate of interaction and quantifying the extent to which various environmental conditions influence pest populations. This study examined the dynamic causal relationships between major pest occurrences and environmental variables in three groundnut-growing states of India, utilizing cointegration and vector error-correction modeling techniques. The Johansen cointegration method has been employed to explore the long term interaction between non-stationary pest populations and environmental variables. The results confirmed a robust long-term connection between pest incidence and environmental factors. Furthermore, unidirectional Granger causality tests supported these findings. The study also investigated impulse response functions, revealing substantial impacts of temperature and relative humidity on pest populations through unit standard deviation shocks to endogenous variables.

Keywords: *Cointegration, Granger causality, Pest population, Vector error correction model*

Pre-harvest forecast of Barley yield using discriminant function analysis on weather variables

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Abstract

In the present paper, an application of discriminant function analysis of weather variables (Minimum & Maximum temperature, Rainfall, Relative humidity, Sun shine hour, Evaporation, and Wind velocity) for developing suitable statistical models to forecast barley yield in Jaipur district of Rajasthan has been demonstrated. Time series data on barley yield for 30 years (1990-91 to 2019-20) have been divided into three groups, viz. congenial, normal, and adverse based on de-trended yield distribution. Considering these groups as three populations, discriminant function analysis using weekly data on seven weather variables in different forms has been carried out. The sets of discriminant scores obtained from such analysis have been used as regressor variables along with time trend variables and barley yield as regress and in the development of statistical models. All six models have been developed. The forecast yield of barley has been obtained from these models for the year 2018-19 and 2019-20 which were not included in the development of the models. The validation of models is checked out based on R2adj, per cent deviation of the forecast, per cent root mean square error (%RMSE) and per cent standard error (PSE) for the reliable forecast of barley yield about two months before the crop harvest.

Keywords: *Barley yield, Discriminant function analysis, Forecast models, Weather variables*.

Forecasting of rice yield of India through non linear growth models

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Abstract

This research paper entitled “Forecasting of rice yield of India through non linear growth models” is based on the secondary data. Data was collected for the years 1963 to 2021 from the official sites of indiastat. For achieving objective, data from 1963 to 2016 were analysed through R- Software and five years data 2017 and 2021 were kept for model validation of yield forecasting of rice in India. For forecasting rice yield in India, three different nonlinear models namely Monomolecular, Gompertz and Logistic, were used. All three non-linear models were fitted to data by using Statistical software R. For validation of assumptions of residuals i.e., randomness and normality of residuals, Run’s test and Shapiro wilk’s tests were employed respectively while for goodness of fit and validation of models, Chi-square test and eight steps ahead forecasting were done. For getting best fitted models for forecasting rice yield, models are compared by seven different statistics R2, RSS, MAPE, MAE, MSE, RMSE, RSE So, after analysing the data, Logistic model is found better for forecasting of rice yield in India with FE% of 6.25% and 5.02 % for year 2020 and 2021 respectively. Forecasted rice yield for the years 2023 and 2024, calculated by the logistic model and found 2.43 t/h and 2.67 t/h respectively. Forecasting model of rice yield for India is best fitted model (i.e., Logistic) as below.

$\hat{Y} = 4.0048 / (1 + (4.0048/0.8612 - 1) * \exp(-0.0321 * t))$

Keyword: *Nonlinear growth model, Forecasting, Run’s test, Shapiro wilk’s test.*

CEEMDAN-Based Hybrid Machine Learning Models for Time Series Forecasting

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Abstract

Accurately predicting time series data is essential for making well-informed decisions and fostering economic development. However, forecasting noisy time series data proves challenging due to their irregular nature and intricate trends. Previous efforts to model complex time series data have explored both stochastic and machine learning techniques. This research introduced a novel hybrid machine learning algorithm based on Complete Ensemble Empirical Mode Decomposition with Adaptive Noise (CEEMDAN) with stochastic models to capture the volatility of weekly potato prices. The smooth decomposed component is forecasted using stochastic models, while other components, identified through Multivariate Adaptive Regression Splines (MARS), are integrated into two distinct machine learning algorithms. The ultimate predictions for the original series are obtained through Particle Swarm Optimization (PSO) optimization. The performance of the proposed algorithm is evaluated using various metrics, revealing that the optimization-based models outperformed the individual models.
Keywords: *CEEMDAN; Ensemble; Hybrid model; Machine Learning; Optimization*

Crop Yield Prediction Using Regression Techniques: A Data Science Approach

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Abstract

Crop modelling is the mathematical and statistical technique of simulating and forecasting crop growth, development, and yield in response to a range of environmental variables. The advancements in computer science and statistics have given rise to a new field called data science. Data science's role has advanced too much in light of the massive growth of data known as "Big Data." Regression models, as indicated by sources, are among one of the best approaches for estimating crop production in the field of agriculture that have been effectively applied recently using data science algorithms. Crop modelling based on regression is an important tool in modern agriculture for

anticipating and optimising crop yields. By analysing historical data and environmental conditions, these models can anticipate agricultural yields in the future, allowing farmers to make well-informed decisions about crop selection, planting timing, irrigation, and fertilizers. The current study concentrated on the advancement of regression methods in the sector of agriculture. The yields of pulse crops are predicted using a variety of regression models, including polynomial, quadratic, and linear.

Keywords: *Variables, Regression modelling, Input variables, Significantly, Optimise resource.*

Agricultural Commodity Price Forecasting using Singular Spectrum Analysis

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Abstract

In recent times, the efficiency of appropriate time series decomposition method has been gained great acceptance. Among various decomposition method, singular spectrum analysis (SSA) is a highly promising technique. Its successful utilization has been demonstrated across various contexts, highlighting its efficacy in capably separating and understanding distinct components within time series data. Therefore, in this investigation, we employed SSA and its forecasting method SSA-LRF to model and predict agricultural price series, specifically focusing on tomatoes in two markets, namely Delhi and Lucknow. Moreover, the outcomes derived from SSA-LRF are compared with those of the SSA-ARIMA and ARIMA models. The comparative analysis was conducted utilizing criteria such as RMSE, MAPE, and MAE. We highlight the supremacy of the SSA-LRF model over the others under consideration, demonstrating the lowest values for RMSE, MAPE, and MAE. This study underscores the significance of decomposition-based forecasting techniques, particularly SSA-LRF, for agricultural price series.

Area Forecasting Model of Cotton in Middle Gujarat

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Abstract

The different statistical models were applied with a view to identify the best model for forecasting area of cotton crop in the middle Gujarat region. The present study was carried out on the basis of secondary data covering the period of nineteen years, (1998-99 to 2016-17). The district level data relating to area, production, productivity and farm harvest prices of cotton were obtained from the published and compiled information by Directorate of Agriculture, Gujarat State, Gandhinagar. The results based on correlation indicated that all the gross return variables viz., lagged gross return, lagged relative gross return, expected gross return and relative expected gross return had positive and significant correlation with the current area of cotton crop. This indicated that gross return variables had significant impact on the current area of cotton. The linear multiple regression technique was employed. The eight single equation and four simultaneous equation models were tried for cotton crop, the following models were selected on the basis of the values of adjusted coefficient of multiple determination. Single equation model-V (0.658) and simultaneous equation model-I (SE-I) were found to be the best fitted for forecast of cotton area. Main factors affecting for area of cotton crop are area and lagged price of pigeon pea.

Single equation model-V:

HECT = 8224.045**-0.219HECTL-0.984*HEPG+0.00001GRCTL+0.587YRSK-0.00002*RRSK

(R^{-2}=0.658)

Simultaneous equation model-I:

HECT = 13592.640**- 3.368** HEPG - 0.255** HECTL - 0.483**EYCT - 0.252**PCTL +0.709** PPGL + 0.0000022*RRSK (R^{-2}= 0.998)

HEPG = 3766.668 - 0.293 HECT + 0.096 HEPGL - 0.073 HECTL - 0.115 EYCT -0.070 PCTL + 0.204 PPGL (R^2= 0.591)

*, ** Significant at the 5, 1 percent level of significance, respectively

Keywords: *Forecasting, cotton, model, simultaneous equation model, area*

Comparative Prediction of Indigenous and Exotic Cattle Population in Uttar Pradesh

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Abstract

The term "cattle" refers to domesticated bovines, namely female cows, male bulls, and young calves, which substantially impact Uttar Pradesh's economy and culture. A cattle rearing has been a traditional livelihood in India and is closely linked to the agricultural economy. The country's Exotic and Indigenous Cattle populations are 51.36 million and 142.11 million respectively (as per the 20th Livestock Census 2019). The goal of this paper is to compare existing forecasting models like ARIMA, Exponential Smoothing, Prophet, and LSTM, for predicting future population trends of indigenous and exotic cattle to promote and formulate context-specific policies for the long-term sustainability of the state's livestock sector in Uttar Pradesh. The results of this study show that the best forecasting predictions are provided by ARIMA (1,1,2) for indigenous cattle and ARIMA (2,1,2) for exotic livestock.

Keywords: *Cattle, indigenous, exotic, forecasting*

Study on the growth rates, instability analysis of sugarcane yield and sugar production in Bihar

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Abstract

In the present study the primary cause of development in production 6.71% and yield 4.70 % of sugarcane during period II (1950-1960) in Bihar and growth in sugar production 7.04% during period-VIII (2010-2020) was cultivation of more productive varieties of sugarcane. At period-I (1940-1950) area (-1.88%), production -5.54%, yield 3.73 % and sugar production (-0.30%) ,all have been seen negative growth. However, the level of instability is lowest during this time and sugar production experienced only modest instability.

Despite the fact that growth was positive overall, the growth rate in both area - 1.88%, -2.47%, -1.98% and -4.02% and production - 5.54%, -1.59%, -3.63% and -4.88% is negative during Period-I (1940-1950), Period-III (1960-1970), Period-IV (1970-1980) and Period-VI (1990-2000).

Similarly, the growth rate for area (2.02%, 0.30%, 1.51%, 0.40%) and production 6.71% , 4.81%, 1.21%, 1.92% is positive during Period-II (1950-1960), Period-V (1980-1990), Period-VII (2000-2010), and Period-VIII (2010-20). It is clear that the area growth was 0.10% and production growth was 1.005 % was positive, even though growth was positive overall period (1940- 2020).

Even though, growth was favourable across the board for all parameters. The growth rate for yield -3.73% , -1.86%, -0.90%, and -0.30% is negative during Period-I (1940-1950), Period-IV (1970-1980), Period-VI (1990-2000), and Period VII (2000-2010) and growth rate for yield 4.70%, 0.90%, 4.60%, 1.00% while growth rate of yield is positive during Period-II (1950- 1960), Period-III(1960-1970), Period-V (1980-1990), Period VIII (2010-2020).

The growth rate for sugar production -0.30%, -0.20%, -2.57%, and -1.98% was negative during Period-I (1940-1950), Period-IV (1970-1980), Period-VI (1990- 2000), and Period VII (2000-2010) and growth rate for sugar production 5.12%, 6.93%, 3.04%, 7.04% while growth rate of Sugar production is positive during Period-II (1950-1960), Period-III(1960-1970), Period-V (1980-1990), Period VIII (2010-2020).It is clear that the yield growth is 1.005% and production growth is 1.11% is positive, even though growth is positive overall period (1940-2020).

During periods I (1940-1950), IV (19970-1980), and VI (1990-2000), the growth in area is negative, but there is less volatility. During these same time periods, the growth in production, yield, and sugar production was also negative, but there is less instability in production and yield. The volatile nature of sugar production is observed in medium amounts. The growth in area is negative and modest during the era VI (1990-2000), but the level of instability decreased over this time. During the period I (1940-1950), growth in production is negative rather modest, although there is less instability overall. During period-VI (1990-2000) as a whole, there is a decline and a low level of increase in sugar output, while the level of instability is medium. Sugarcane crop cultivation in Bihar has varying trends in terms of area, production, yield, and sugar production; but, on the whole, it has been steadily expanding over the course of the entire study period.

Keywords: *Compound Growth Rate, Ordinary Least Square method, Instability analysis and Cuddy-Della Valle index.*

Forecasting of Cotton Production in Gujarat Using Arima

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Abstract

The research was undertaken to forecast the production of cotton in Gujarat using ARIMA. This study evaluates the ability of popular linear auto-regressive integrated moving average (ARIMA) models. Gujarat leads as the primary contributor to India's cotton production, accounting for approximately 27% of the nation's overall cotton production. Cotton possesses the great value among all the fibre crops and has significant influence on economics and social affairs of the world from ancient time The quality of any other fiber crop cannot be compared to that of cotton. The Arabic word quont, which means "king of fiber" or "white gold," is the source of the English name cotton. The study's goals were fulfilled by using time series secondary data from 1981–1982 to 2018–19 on the production of the cotton crop for the entire state of Gujarat. In the current investigation. The attainment of the study's objectives involved the utilization of ARIMA modeling. The initial 38 years of data were employed to establish the trend line, while the subsequent 34 years of data served the purpose of training and the remaining four years of data were used for treatment. The different orders of ARIMA models (p, d, q) were judged on the basis of Auto-correlation Function (ACF), Partial Autocorrelation Function (PACF) at various lags. Different family ARIMA models were fitted, and from these, the models were selected based on the lower values of Akaike's Information Criterion (AIC) and Schwartz-Bayesian Criterion (SIC). Various families of models ARIMA (1, 2, 1), ARIMA (0, 2, 1), ARIMA (1, 2, 2), ARIMA (5, 2, 1) and ARIMA (4, 2, 1) models were tried. Among the ARIMA models, the ARIMA (0, 2, 1) model was found to be the best-fit model based on RMSE and MAPE. In modifying ARIMA (0, 2, 1), The ARIMA model (AR (1) MA (2) MA (1)) was selected based on the lower value of AIC (22.44), SIC (22.67) and high value of adjusted R2(73.97%) and stated better for forecasting, the value of forecast error varied from -100.65 to 5.39 per cent.

Keywords: *forecast, cotton, ARIMA, production, AIC, SIC.*

Ensemble modelling for predicting the potential geographical areas for *Trianthema portulacastrum* under future climate

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Abstract

Weeds are considered as the most damaging biotic constraint to agricultural production, in addition to threatening agro-biodiversity and natural water bodies. Further, climate change may be the driver for global range expansions and changes in life cycles of weeds. Trianthema portulacastrum is a serious threat to biodiversity and responsible for significant losses in greengram, maize, soybean, and peanut yield and has an allelopathic effect on soybean. In the current study, species distribution modelling approach is used to study the current geographical distribution of T. portulacastrum and to predict the future range changes under RCP 4.5 and 8.5 for the years 2050 and 2070 using ensemble-modelling approach. For the purpose, occurrence data for T. portulacastrum was obtained from various sources, including India Biodiversity Portal, GBIF, CABI, published literature etc. Eight bioclimatic variables along with elevation layer and soil layer were used for model development using ensemble-modelling approach. For developing the ensemble model, five algorithms that include two regression approaches (Generalised Linear Model & Multivariate Adaptive Regression Splines) and three machine learning methods (MaxEnt, Artificial Neural Network and Random Forest) were used. Ensemble modelling approach gave highest TSS (0.606), AUC (0.872), and Kappa statistc (0.547) value as compared to the individual models considered in the study. The predictor variables that are predominantly influencing the model are minimum temperature of the coldest month, annual precipitation and temperature seasonality. Model suggested that T. portulacastrum will undergo significant range changes under all the future climatic scenarios with gain in habitat suitability.

Intuitionistic Fuzzy Time Series Forecasting Based on Long Short Term Memory

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Abstract

In recent years, deep artificial neural networks, including Long Short Term Memory (LSTM), have demonstrated superior forecasting performance compared many other neural network models. While there have been a few fuzzy time series forecasting models incorporating LSTM in the literature, LSTM has not yet been significantly applied to intuitionistic fuzzy time series (IFTS) forecasting methods. This motivates the introduction of a novel IFTS forecasting approach utilizing LSTM. In this proposed method, the establishment of fuzzy relations relies on the LSTM artificial neural network. Subsequently, membership and non-membership values are determined using intuitionistic fuzzy c-means. These values are then combined as inputs for the LSTM through a minimum operator. This approach effectively incorporates lagged crisp values as inputs for the LSTM, resulting in a high-order IFTS model. The LSTM artificial neural network architecture entails multiple inputs (membership values, non-membership values and target variable) and a single output. For evaluating the accuracy of the deep IFTS-LSTM model, the wholesale prices of five important pulses from different markets of India has been utilized. It has been found that for data under consideration the IFTS-LSTM model has outperformed the traditional Auto Regressive Integrated Moving Average (ARIMA), Artificial Neural Network (ANN) and LSTM model in terms of different accuracy measures like Root Mean Square Error (RMSE), Mean Absolute Percentage Error (MAPE) and Mean Absolute Error (MAE).

Keywords: *Crisp set; Deep learning; Fuzzy set; Intuitionistic fuzzy c-mean; Intuitionistic fuzzy time series; Long short-term memory.*

Time Dependent Dynamic Ensemble Method for Pest Population Prediction in Rice Crops

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Abstract

Agricultural pests in India constitute a complex and significant menace to the country's vital agricultural sector, which forms the backbone of its economy and food supply. Pests can cause extensive harm to crops such as rice, wheat, and pulses on an immense scale. Rice (Oryza sativa) being one of the world's most vital staple crops, is feeding a significant portion of the global population. However, its production is continually threatened by various biotic stressors, among which the yellow stem borer (Scirpophaga incertulas) stands out as a notorious pest. Forecasting the pest population holds significant importance within agriculture and pest management for a variety of compelling reasons. It equips farmers with the knowledge needed to make informed decisions regarding pest control strategies. This study will utilize ensemble method approach based on time dependent dynamic weight for predicting population of yellow stem borer in rice crop.

Keywords: *ARIMA, Count data, Ensemble method, GLARMA, Negative binomial, Pest prediction*

Quantifying Agricultural Diversification Trends: A Statistical Analysis in Gujarat

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Abstract

In Gujarat, the economic well-being of small and marginal farmers hinges on agriculture, with crop diversification viewed as a promising strategy for upliftment. This study explores 20 years of time series data (2000-01 to 2019-20) to analyse the growth, trends, and determinants of crop diversification. Notable growth rates are observed in gram cultivation (area 8.61%, production 13.38%, productivity 5.16%), while cash and

commercial crops like cotton, tobacco, and cumin exhibit higher and significant growth. The cubic model effectively forecasts crop areas, and technological adoption positively impacts cash and commercial crop density (2008-2012). Despite a decrease in diversification indices, the reduction is not pronounced. The year 2003-04 recorded the highest diversification index. Influential factors include negative effects of bank credit (X9) and positive impacts of rainfall (X1). Findings stress the need for Gujarat to implement policies promoting agro-processing, agricultural value addition, and technological transformation in farm input industries, fostering rural employment-led economic growth to alleviate poverty.

Keywords: *Crop Diversification Index (HI, OI, EI, MEI, CEI); Growth Rate; Instability; Multiple Regression Analysis.*

Seasonal approach of Deep Learning models for forecasting rainfall series

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Abstract

Incorporation of seasonality in a model improves the modelling as well as forecasting performance of seasonal series. There are various deep learning models namely Recurrent Neural Network (RNN), Long Short-Term Memory (LSTM) and Grated Recurrent Unit (GRU) that are used to capture the various underlying patterns of a time-series data. It is often noticed that in presence of seasonality, these models do not perform as per the expectations. Hence, paving way for incorporating seasonal attribute to these models. Thus the introduction of Seasonal Long Short-Term Memory (SLSTM), seasonal Grated Recurrent Unit (SGRU) and Seasonal Recurrent Neural Network (SRNN) aimed at forecasting seasonal time-series such as rainfall data. These models are trained by incorporating seasonal attributes related to quarters alongside historical time-series data. These seasonal attributes can be input into these network model either individually or in combination. The models have been applied to rainfall data of Assam and Meghalaya subdivision of India from the year 1901 to 2017 collected from the official website of India Meteorological Department, New Delhi (https://mausam.imd.gov.in/). To evaluate the effectiveness of the proposed models, we conducted a comparative analysis among the conventional and seasonal LSTM, GRU and RNN using five performance metrics: Mean Absolute Error (MAE), Root Mean

Squared Error (RMSE), Normalized Mean Absolute Error (NMAE), Normalized Mean Absolute Error with Range (NAME_R) and Normalized Mean Absolute Error with Interquartile-Range (NMAE_IQR). Experimental results reveal that the proposed models perform superior to the conventional method, exhibiting a significantly lower error rate.

Keywords: *Rainfall, Seasonality, Deep Learning, RNN, LSTM, GRU*

Arima Model for Area, Production and Productivity of Cumin (*Cuminum cyminum* L.) in Major Five Districts and Gujarat

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Abstract

The present study was carried out to estimate the trends of area, production and productivity of cumin crop in major five districts (Banaskantha, Mehsana, Surendranagar, Rajkot, and Ahmedabad) and Gujarat state. The time series data on area, production and productivity of major five districts of cumin crops and Gujarat state for the period 1990-91 to 2018-19 (except Banaskantha and Mehsana districts, due to bifurcation of these districts it was only for the year 2000-01 to 2018-19) were collected from the published reports by Directorate of Agriculture, Gujarat state, Gandhinagar. The data from 1990-91 to 2015-16 were used for model building and remaining for validation of the forecast model. An attempt was made in present investigation to ARIMA models to arrive at a methodology that can precisely explain the fluctuation in area, production and productivity for cumin crop in different districts of Gujarat state and to compare different models.

The Autoregressive Integrated Moving Average (ARIMA) models were also fitted to the original time series data after checking the stationary condition of data. The suitable model was identified on the basis of significance of regression coefficients, R2, root mean square error, mean absolute error, normality (Shaprio-Wilk test) and randomness of residual’s (Run test) distribution. The different orders of ARIMA models (p, d, q) were judged on the basis of autocorrelation function (ACF), partial autocorrelation function (PACF) at various lags. Different possible ARIMA models were

fitted and from these, the models were selected on the basis of significant autoregressive and moving average term, Akaike's Information Criterion (AIC), Schwartz-Bayesian Criterion (SBC) values and normality (Shaprio-Wilk test) and randomness of residual's (Run test) distribution.

Among the ARIMA models, ARIMA (1, 1, 0) model was found suitable to explain the pattern of cumin area of Banaskantha district and at state level while, for cumin area of Ahmedabad district, ARIMA (2, 1, 1) model was found suitable.

Among ARIMA models, ARIMA (1, 0, 0), ARIMA (1, 1, 0) and ARIMA (1, 1, 1) models were found suitable to explain the trend of cumin production in Mehsana, Rajkot and Ahmedabad districts, respectively. In rest of the districts and at state level, ARIMA models failed to satisfy one or more criteria of selection.

ARIMA (1, 0, 2), ARIMA (1, 1, 0), ARIMA (2, 1, 0), ARIMA (1, 1, 1) and ARIMA

(0, 1, 1) models were selected to explain the trend of cumin productivity in Banaskantha, Mehsana, Surendranagar, Rajkot and Ahmedabad districts, respectively. At state level none of the ARIMA model was selected due to lack of one or more criteria of selection.

Thus, in general because of crucial requirements of model selection criteria in ARIMA models, few models could get selected. There is need to examine different statistical techniques for fitting the trend of area, production and productivity of cumin.

Keywords: *forecast, Cumin, ARIMA, Area, Production, Productivity, AIC, SIC.*

The Co-Integration Based Support Vector Regression Model and Its Application in Agriculture

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Abstract

This paper presents a novel approach for forecasting agricultural prices using a co-integration based support vector regression (SVR) model. The proposed method combines the advantages of co-integration and SVR to accurately capture the underlying co-integration among two co-integrated agricultural data series. In the study, an effort was made to improve the prediction ability of the standard SVR model by incorporating the error correction term (ECT) obtained from the co-integration analysis. The ECT of the error correction model is used as auxiliary information in the SVR model for

forecasting the monthly wholesale price index of fruits. The performance of the model is evaluated on the basis of fit statistics like RMSE, MAD, MAPE and ME. The study suggests that the researchers should also focus on the co-integration analysis for better forecasting the accuracy of agricultural commodities.
Keywords: *Co-integration, Support vector regression, Error correction term, Prediction ability Agricultural price data.*

Stability Assessment of Finger Millet [*Eleusine coracana* (L.) Gaertn.] Genotypes Through TOPSIS Method and Validation with MTSI

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Abstract

The susceptibility of crop growth to biotic and abiotic stresses is escalating due to global climate change, underscoring the urgency to develop improved crop varieties. At the moment, the bulk of the crop improvement primarily focused on staple cereals such as rice, wheat, and maize, sidelining minor cereals like finger millet [Eleusine coracana (L.) Gaertn.]. The selection of an appropriate cultivar or variety tailored to specific environments is crucial for all crops. the identification of stable genotypes through effective stability measures is essential to minimize risks for farmers and enhance economic outcomes. Amid various stability measures, this research adopted the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) as a comprehensive method for selecting a stable finger millet genotype adaptable to environmental variations. Analyzing data from three distinct environments and 36 genotypes, the study identified genotype G25, with the lowest relative closeness value (0.01), as the most stable among all and the genotypes G8 and G14 identified as the second and third stable genotype. This outcome is validated using the Multi Trait Stability Index (MTSI) model, affirming the suitability of TOPSIS in discerning stable genotypes, offering insights for sustainable and resilient agriculture in the face of changing climates. The comparison of parametric and non-parametric methods utilised in the study was effectively carried out using spearman rank correlation, which does not require any

pre-requisite assumptions about the observations. There was significant association among Wricke's ecovalence and Thennarsu's non-parametric stability measure $NP_i^{(1)}$. Mean yield showed strong association with GGE PC1 and showed positive association with all the stability measures except Eberhart and Russell stability value, AMMI PC2 and Thennarsu's non-parametric stability measure $NP_i^{(1)}$.

Keywords: *Stability, TOPSIS, MTSI, Finger millet, Parametric, Non-parametric*

Assessing Spatial Market Integration of Chickpea Prices in Gujarat: A Vector Error Correction Mechanism (VECM) Approach

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Abstract

This study examines the spatial market integration of chickpea prices in Gujarat, evaluating the relationship between spatially separated markets using a co-integration technique within a Vector Error Correction Mechanism (VECM) framework. Secondary data on monthly wholesale prices spanning seventeen years (2005 to 2022) were collected from selected Agricultural Produce Market Committees (APMCs) in Gujarat. Market selection was based on chickpea arrival volumes, focusing on Vadodara, Banaskantha, Ahmedabad, and Surat. Stationarity tests using the Augmented Dickey-Fuller (ADF) test indicated first-order difference stationarity for all price series. Johansen's co-integration test revealed the presence of at least three co-integration equations for chickpea (Vadodara, Banaskantha, Ahmedabad) at a 5% significance level, indicating both long-run and short-run integration in the chickpea markets. The study suggests that the Ahmedabad market exhibited higher efficiency in reacting to price news compared to Vadodara and Banaskantha markets.

Keywords: *Chickpea, Wholesale price, Correlation, ADF test, Market integration, VECM.*

TS 5: Modern Statistical Designs and tools for Effective Experimentation

INVITED TALK

A note on Balanced and Partially Balanced Semi-Latin Rectangles

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A generalization of the Latin square (LS) is the semi-Latin square (SLS), which is an arrangement of treatments/symbols in $v \times v$ row-column setup such that each row-column intersection contains $k > 1$ units and each treatments occurs exactly once in each row and also once in cach column. Semi-Lain rectangles are the generalization of Semi-Latin square which are useful for situations when the number of levels of both the nuisance factors (factors of heterogeneity) are not same. Balanced Semi-Latin rectangles (BSLR) are the subclass of Semi- Latin rectangles (SLR) which are generalizations of Latin squares and Semi-Latin squares (SLS). Such types of designs are more useful in plant disease experiments in which we can consider plants as column, half-leaves as experimental units and height of leaves as row. In this article we introduce the design, Partially BSLRs which form a subclass of Semi-Latin rectangles with the property that their quotient block designs form Partially balanced incomplete block designs (PBIBDs). And also develop construction methods of partially balanced SLRs for v treatments in h rows and p columns, where $v \geq 2, h, p > 1$ using some combinatorial approaches for generation of initial blocks/starters and the cyclic method. We also propose four new construction methods of Balanced and Partially halanced SLR designs. Additionally, an R package named "slr" has been developed to facilitate the implementation of the proposed construction methods

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Optimal Equivalent Estimation Balanced Incomplete Split Plot Designs

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In agricultural, post-harvest and processing, engineering and industrial experiments factors are often differentiated with ease with which they can change from experimental run to experimental run. This is due to the fact that one or more factors may be expensive or time consuming to change i.e hard-to-change factors. These factors restrict the use of complete randomization as it may make the experiment expensive and time consuming. One cost effective alternative for these situations may be the use of split plot designs that reduces the number of independent settings of the hard to change factors by allocating them to whole plots or main plots and the easy-to-change factors to subplots. In general model estimation of split plot designs require the use of generalized least squares (GLS). However for some split-plot designs ordinary least squares (OLS) estimates are equivalent to generalized least squares (GLS) estimates. These types of designs are known as equivalent-estimation split-plot designs in literature. This is because split-plot designs for which OLS and GLS produce the same factor-effect estimates offer the advantage that the estimates of the effects do not depend on the estimates of the variance components in the split-plot model. They possess the property that the OLS estimator of the fixed effects in the split-plot model is equivalent to the GLS estimator. This property enables estimation of the fixed effects without estimating the variance components of the model. Further, since split-plot designs are subject to lack of randomization, therefore trend effects may affect the response under this set up. Here, optimal equivalent estimation balanced incomplete split plot designs for different experimental setting have been obtained where the designs will be balanced in the sense that number of subplot per whole plot will remain equal.

Keywords: *Hard-to-change factors, equivalent-estimation, Split-plot, trend factor, D and D_t – criterion*

Ordering Factorial Experiments: An Overview

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Factorial experiments are experiments that investigate the effects of two or more factors each at two or more levels on the output response of a process. Estimating the effects of various factors on the output of a process with a minimal number of observations is crucial to being able to optimize the output of the process. However, in some experiments, not only the level combinations of factors, but also the addition orders will affect the responses. In literature, experiments considering both the levels of factors and addition orders of components have been studied as ordering factorial experiments (Yang et al., 2023). Here a new series of two level ordering factorial experiments have been obtained.

Keywords: *D optimality, Factorial experiments, Order of Addition*

Experimental Designs for Breeding Trials

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Experimental designs forms the basic step in planning, conducting and inferring about breeding trials. The information regarding combining abilities is always desirable for a breeder to select best parental lines. Mating designs involving higher order crosses (triallel and tetra-allele cross) can be used advantageously to get this information. There are varied experimental situations involving different type of breeding techniques like, breeding experiments for test vs. test line comparisons, breeding experiments for test vs. control line comparisons and augmented breeding trials. Designing higher order mating experiments for all these situations to provide maximum information on combining abilities by utilizing the limited resources is a researchable challenge. General methods of construction of these designs along with the information matrices related to general combining abilities variance factors, amount of information factors and efficiency factors have been discussed

ABSTRACT

Applying Sequential Multiple Assignment Randomized Trials to a Hypothetical Study for Improving Milk Production in Lactating Dairy Cows

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Abstract

Implementing a Sequential Multiple Assignment Randomized Trial (SMART) design is crucial for enhancing milk yield in dairy farming. This systematic approach, guided by decision rules, allows farmers to adapt interventions based on individual cow variations. Our objective is to employ SMART Design for Augmenting Milk Production in Lactating Dairy Cows. In the first stage, one group receives a mix of tropical legume (Phaseolus calcaratus) and ruzi grass, while the second group is introduced to Virtual Reality (VR) goggles depicting green pastures. After 15 days, non-responders (milk production remained stagnant or declined) in both groups are identified. Non-responders in the first group are randomized into VR goggles and VR combined with the tropical legume and ruzi grass. Similarly, non-responders in the second group switch between the mix of tropical legume and ruzi grass and the combination of VR with tropical legume and ruzi grass, maintaining the intervention for responders. After an additional 15 days, the effectiveness of VR combined with the tropical legume and ruzi grass in boosting milk production is evaluated. This cost-effective SMART design comprehensively assesses optimal intervention effects, including non-responders, providing valuable insights for maximizing milk yield in dairy farming.

Keywords: *SMART; Adaptive design; RC*

Construction of Second Order Rotatable Design involving Qualitative Factors

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Abstract

There are numerous instances in agricultural experiments where both qualitative and quantitative factors are important. For instance, in fertilizer trials, the response or yield of a crop varies not only on different fertilizer doses but also on the manner of application, such as broadcasting, behind the ploughing, or foliar application. The quantity of fertilizer applied is a quantitative variable in this situation, whereas the application method is a qualitative variable. We describe a structured approach for creating second order rotatable response surface designs that are both symmetric and asymmetric in some qualitative and quantitative factors and are valuable for modelling and optimization of experiments. In an asymmetrical design, quantitative factors are at unconstrained levels and qualitative factors are at 3 levels while quantitative factors are at 5 levels and qualitative factors are at 3 levels in a symmetrical design. Design consist of three portions: factorial runs, axial runs and center runs. Lists as well as graphs of 3 to 10 factors along with G and D efficiencies are also presented.

Keywords: *D efficiency; G efficiency; Response surface methodology; Rotatability; qualitative factor; quantitative factor.*

Central Composite Design (CCD): A Statistical Tool for Optimizing Nutrients for Sesame in Southern Laterites (AEU 8), Kerala

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Abstract

Green revolution era has been the golden age of agriculture sector, but irrational crop and nutrient management practices have led to decline in productivity and sustainability. Growing concerns on impaired soil health, low nutrient use efficiency and environmental pollution have paved way to develop unique agro-ecological based nutrient management practices that synergize crop and soil dynamics. Field experiments were conducted at Coconut Research Station, Balaramapuram, Kerala to optimise the fertilizer dose for sesame in AEU 8, during Rabi, 2021-22 and 2022-23 using CCD, with 20 runs viz., T1:31:20:16, T2:64:20:16, T3:31:50:16, T4:64:50:16,T5:31:20:34, T6:64:20:34, T7:31:50:34, T8:64:50:34, T9:20:35:25, T10:75:35:25, T11:48:10:25, T12:48:60:25 T13:48:35:10,T14:48:35:40, T15 to T20: 48:35:25 kg NPK ha-1. The variety used for the study was Thilak. By plotting the response surface curves from the seed yield, the optimum NPK requirement was determined. During Rabi 2021-22, 34.89:25.46:6.81 kg NPK ha-1 (N1) and during Rabi 2022, 33.60:21.09 :3.22 (N2) and 33.62 :33.66 :2.97 (N3) kg NPK ha-1,were identified as the optimum nutrient dose for sesame in AEU 8. The economic dose was determined by analysis of the pooled data on seed yield of both seasons using RBD (N4:31:20:16 kg NPK ha-1).The results were validated using split plot design during Rabi 2023-24. Six promising sesame varieties viz., Kayamkulam 1 (V1), Thilathara (V2), Thilarani (T3), Thilak (T4), GT-10 (V5) and TMV-7 (V6) were taken in the sub plots, while the identified optimum nutrients and 30:15: 30 kg NPK ha-1(blanket recommendation) were taken in the main plots. The results revealed that the variety GT-10 fertilized with 33.60 :21.09 :3.22 kg NPK ha-1 produced the highest seed yield (1277.19 kg ha-1). It could be concluded from the results that CCD would help to optimize the fertilizer dose for sesame in AEU 8 compared to RBD. For higher yield in sesame, only 3.22 kg K ha-1 was required which is 89.26 % lesser than blanket recommendation. However N and P requirement was higher. Therefore, CCD could be considered as the best statistical tool for finding out the optimum nutrients for higher yield in crops.

Evaluation of Forage Maize Genotype for Stability Analysis Using Non-Parametric Methods

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Abstract

Evaluation of stable performance and high yield is essential for yield trials conducted in different environments. The fifty promising forage maize genotypes were evaluated in four different environments (Kharif: 2021, Late Kharif: 2021, Rabi: 2021-22 and Late Rabi: 2021- 22) at Main Forage Research Station, Anand Agricultural University, Anand in RCBD with three replications to study their adaptability to varying climatic conditions. The pooled ANOVA results showed significant variation of genotype, environment and G x E interaction. Significant genotypic variance indicated genetic diversity among genotypes for green fodder yield. For the yield stability of genotypes, different non-parametric methods ($Si^{(1)}$, $Si^{(2)}$, $Si^{(3)}$, $Si^{(4)}$, $Si^{(5)}$ and $Si^{(6)}$) were employed. Non-parametric measures revealed that AFMC-2, AFM-18, AFM-29 and AFMC-3 had lowest value of measures and had higher yield as compared to overall mean yield thus genotypes AFMC-2, AFM-18, AFM-29 and AFMC-3 were found stable over environment while IC-130725, BAIF-252, IC-130791 and BAIF-155 were found highly unstable genotypes. This indeed supported by the plots portrayed from mean yield (kg $plot^{-1}$) Vs $Si^{(1)}$ and $Si^{(2)}$ values. From plots, Section 1 suggest that genotypes (AFM-33, AFM-18, AFM-23 and AFMC-3) with high yield and lower values of $Si^{(1)}$ and $Si^{(2)}$ can be considered as stable and well adapted to all environments. Section 2 suggest that genotypes (African Tall, Pratap Makka, AFMC-1, AFM-20 etc.) with high yield and higher values of $Si^{(1)}$ and $Si^{(2)}$ can be considered as increasing sensitivity to environmental fluctuations and greater specificity of adaptability to high yielding environments. Section 3 referring poorly adapted genotypes to overall environments which were IC-130725, BAIF-252, IC-130791 and BAIF-155 etc. Section 4 exhibits that genotypes (GDRFG-1643, IC-77541, Origin Mexico-6360, AFM-34 etc.) were low yielding and small $Si^{(1)}$ and $Si^{(2)}$ values indicative of greater resistance to environmental changes and therefore increasing specificity of adaptability to low yielding environments.

Keywords: *Forage maize crop, Yield stability, Non-parametric methods, G x E interaction*

Statistical Tool for Assessing the Effect of Seed Burial Depth on Germination and Growth of Chocolate Weed (*Melochia corchorifolia* L.)

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Abstract

Chocolate weed (*Melochia corchorifolia* L.), a tropical perennial woody shrub, is one of the predominant broad-leaved weeds in uplands. The placement of a weed seed in the soil profile impacts the likelihood of emergence and growth of seedlings. Discovering the relationship between the position of weed seed and its capacity to emerge from varying depths facilitates weed ecology study. Experiments were conducted in a screenhouse at College of Agriculture, Vellayani, from March to May 2021, to determine the effects of seed burial depth (0, 2, 4, 6, 8 and 10 cm) and seed scarification on germination parameters (seedling emergence percentage, germination index (GI), germination rate index (GRI), speed of germination (SG), seedling vigor index I and II) and growth parameters *of M. corchorifolia*. The results of the study revealed that, seedling emergence of *M.corchorifolia* was influenced by depth of seed burial. Seeds buried at 2 cm depth exhibited the greatest levels of emergence (46.00%) The seedling emergence from a depth of 10 cm witnessed a reduction to the extent of 88.48 percent in comparison to the emergence from a depth of 2 cm. Germination indices were found to be significantly higher at a burial depth of 2 cm. A further increase in depth resulted in reduction of germination indices. The seeds buried at 10 cm depth exhibited a decrease in SG, GI and GRI by as much as 93.22, 90.39 and 92.53 per cent respectively as compared to the seeds buried at 2 cm depth. Longer seedlings with greater biomass were observed in seeds positioned at a shallow depth (2 cm), while greater depths (6, 8, and 10 cm) resulted in a notable decrease in seedling length. A decrease in seedling length and biomass to a tune of 73.75 and 93.37 percent were noted in seeds positioned at a depth of 10 cm, as compared to those at 2 cm depth. The application of regression analysis in weed ecology is substantial, to quantify relationships between variables. The regression analysis investigating the influence of depth on different germination and

growth parameters of *M. corchorifolia* revealed highly significant negative regression values. Regression models for shoot length, expressed as Y = 34.951 - 2.027x, suggests that with every 1 cm increase in depth, the shoot length decreases by 2.027 cm. Similarly, the regression equation for root length, given as Y = 37.468 - 2.345x, indicates that for every 1 cm increase in depth, the root length decreases by 2.345 cm. Regression models on optimal burial depth for *M. corchorifolia* L. can provide valuable insights into their ecological preferences and aid in the development of targeted weed management practices. By identifying patterns and relationships, regression analysis enables the development of predictive models to forecast weed population dynamics, growth patterns, and response to varying conditions.

Optimum Size and Shape of Plots for Field Experiments on Sesame

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Abstract

An uniformity trial on sesame crop was carried out at Seed Technology, S. D. Agricultural University, Sardarkrushinagar during kharif season in the year 2022-23 to find out optimum plot size, plot shape and number of replications. The popular variety GT 3 was grown for this purpose and yield data were collected from 600 hundred basic units. The dimension of one basic unit was 1 m x 1.20 m constituting 2 rows each of 1meter length. The Maximum curvature method (Federer, 1955) and Fair field Smith's variance law (Smith, 1938) were used for the same. The variability as judged by coefficient of variation per unit area (C.V. %) decreased from 24.24 to 1.94 per cent with increase in plot size from 1 basic unit to 300 basic units. Based on experimental research, it was concluded that, a plot of 18 m^2 size having shape of 6 rows each of 5 m length (5 m × 3.6 m) found optimum (net plot) with minimum 3 replications at 5 per cent standard error is recommended for filed experiments on sesame crop.

Keywords: *Optimum plot size, Coefficient of variation, replications, sesame*

Construction of Balanced Semi-Latin Rectangles in block size two

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Abstract

Balanced Semi-Latin rectangles (BSLR) are the subclass of Semi-Latin rectangles (SLR) which are generalizations of Latin squares and Semi-Latin squares (SLS). Such types of designs are more useful in various agricultural as well as industrial experiments in which one of the effects can be consider as column effect and another as row effect, where the intersection of effects can only accommodate with two units. This article introduces two construction methods for BSLR designs with a block size of two. Additionally, an R package named "slr" has been developed to facilitate the implementation of the proposed construction methods.
Keywords: *Semi Latin Rectangle, Balanced Semi-Latin rectangles, canonical efficiency factor, average efficiency factor.*

Integrated Breeding Designs for Hybrid Varietal Production

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Abstract

An integrated breeding design (InBrD), taking care of both mating plan for selection of crosses and environmental design for subjecting the offsprings to specific environmental conditions, will offer a unified strategy for the breeders. Nested incomplete block (NIB) designs form a very useful sub-class of incomplete block designs used to eliminate two sources of variation where one source of variation is nested within the second. The construction procedure of NIB designs is easy and the method yields a wide range of designs. Those designs with sub-block size 2 or 3, with contents treated as lines, can be directly used to get desired partial diallel or partial triallel crosses, respectively. The method of construction has been illustrated with examples.

Keywords: *Degree of fractionation, Nested incomplete block designs, Partial diallel crosses, Partial triallel crosses*

Genetic variability, Correlation and path analysis of 185 F3 progenies of black gram [Vigna mungo (L.) Hepper] for seed yield and related traits using augmented block design

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Abstract

Black gram is an important autogamous pulse crop with cleistogamous condition, hence showing minimal variation. So, the experiment was done to assess the black gram F3 progenies of cross NUK-15-02 × GU-1 along with four checks GU-1, GU-2, GU-3 and T-9 for genetic variability parameters, correlation and path analysis of eleven quantitative traits related to seed yield in Augmented Block Design. Analysis of variance showed that F3 progenies exhibit substantial variability for all the attributes considered in this study. The highest seed yield per plant was depicted by progenies A-74 (31.38 g), A-193 (30.60 g) and A-11 (29.08 g). High GCV and PCV values were observed for seed yield per plant, pods per plant, clusters per plant, branches per plant and harvest index, demonstrating the potential for improvement through selection. Plant height, branches per plant, clusters per plant, pods per plant, harvest index and seed yield per plant showed strong heritability in conjunction with high genetic advance. Strong and positive relationships were found between the pods per plant, harvest index (%), clusters per plant, branches per plant and plant height (cm) and the seed yield. Above listed characteristics may simultaneously increase the seed yield per plant (g), hence they may all be regarded as significant yield-attributing characteristics. Path study showed that pods per plant, followed by clusters per plant and branches per plant, had a direct and beneficial impact on seed yield per plant (g). So, selection for such traits is recommended to improve black gram due to additive gene action.

Prediction of Mango yield for Durg District of Chhattisgarh

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Abstract

Mango yield and weather variable viz. minimum temperature, maximum temperature, relative humidity, sunshine, rainfall and wind velocity weekly weather data over a span of 18 years data period (2004-2021) for Durg district of Chhattisgarh have been used in study. The model have been developed by (SRA) Stepwise Regression Analysis (forward method) and (MLR) Multiple Linear Regression on weather data. The stepwise regression model fitted on 14 generated weather variable along with T, i.e. 8 parameters have been used. The 8 generated weather variable along with T has been used to fit the Multiple Linear Regression. In Unweighted weather variables the significant and value of R^2 found in Durg district 0.02 and 0.29 respectively. In Weighted variables the significant and value of R^2 found in Durg district 0.01 and 0.89 respectively. In validation model RMSE and R^2 for Durg district i.e. 266.73 and 0.94 respectively.

Stability analysis in black gram (*Vigna mungo* (L.) Hepper) using parametric and non-parametric methods

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Abstract

Multi-locational trial of twenty black gram genotypes was conducted at Vadodara, Jabugam, Devgadh Baria, Derol and Dahod locations during summer season of year 2016. The experiments were conducted in RBD with two replications across five environments. The data were subjected to stability analysis to determine phenotypic stability of genotypes using parametric and non-parametric methods. In Pildebrand's

methodHHHHH ooled analysis, Genotype x environment was found significant which indicated that the genotypes performed differently in different locations and there was need to found stable genotypes using non-parametric and parametric stability methods. GEI contributed 84.02 and 12.36 per cent of trial variation, respectively. Genotype effects were found significant in all locations except Jabugam. The present study revealed that the non-parametric methods of stability analysis may be used as substitute of parametric methods as no assumptions are needed about the distribution of observed values and they reduce the bias caused by outliers and they are easy to use and interpret. The most stable genotypes according to the nonparametric methods were G11 and G15 whereas genotype G18 was proved to be the most unstable genotype.

Keywords: *Non-parametric, parametric stability, black gram*

Optimal Covariate Designs: An overview

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Abstract

In many of the experiments, covariates are available and are of an immense importance. The orthogonal estimation of covariate parameters on one side and the treatment contrasts and/or block contrasts on the other side is a desired property. If the components in the two sides are “orthogonal”, then we can invoke optimality separately in each side and thereby characterize optimal designs in such a set-up in the area of linear models and design of experiments. The choice of values of the covariates for a given block design attaining minimum variance for estimation of each of the parameters is of concern. Optimum covariate designs in simple setups such as completely randomized design (CRD), randomized complete block design (RCBD) and some series of balanced incomplete block design (BIBD) has been worked out.

Keywords: *Covariate, AVCOVA, Optimality, Orthogonality.*

TS 6: Achievable-Relevant Time bound (ART) Agricultural Informatics

INVITED TALK

Digital Agriculture: A Roadmap for Achievable Transformation in the 21st Century

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Global agriculture is facing remarkable changes due to the technological revolution, including the digital revolution, progressive growth in middle-income groups, sprawling urbanization, fast-changing food preferences, market fluctuations, and climate change and environmental degradation. These changes offer unique challenges and prospects for transforming agriculture into more productive, socially equitable, economically remunerative, inclusive, and environmentally sustainable. In India, in the past 50 years, with the Green Revolution in the mid1960s, followed by the White, Yellow, and Blue Revolutions – together known as the Rainbow Revolution, overall agricultural and food production amplified over four-fold. These developments have aided the nation in the reduction of its poverty and hunger levels by 50 to 70 percent. Despite the exceptional improvement made in production and economic growth and the strong political support, India is confronted with an enigmatic situation. Nearly one-fifth of the world's hungry and 35 to 40 percent of the world's undernourished and stunted children have their homes in India. India's agrarian economy is home to over one-third of the world's small and marginal farm holders, and these small and marginal farmers encompass most of the country's hungry and poor. Soon, India will attain a Population of 1.7 billion by 2050. The growing food demand, with only 2.3 percent of the world's land and 4 percent of global freshwater, is a challenge the country will face. Against these odds, to feed a population of 1.7 billion by 2050, land productivity would be required to be enhanced by four times, water productivity by three times, and labour productivity by six times. And, these goals can be attained only by creating and widely adopting innovative science-based policies and efficiency-enhancing Digital and precision technologies [1].

The agricultural industry is presently in the midst of a transformative revolution driven by digital technology. This revolution, with Industry 5.0, the Internet of Things (IoT), Artificial Intelligence (AI), and Nano Technology, among others, is gaining prominence, often called the "Digitalization of Agriculture," is redesigning how farmers approach crop cultivation, livestock management, and farm decision-making processes. From precision farming to data-driven insights, the digital transformation of agriculture promises to expand efficiency, sustainability, and global food security in the 21st century. The digital transformation of agriculture incorporates a broad spectrum of technologies and innovations that are reshaping traditional farming practices. Digital technology could be the answer to this problem [2].

The Technology Driving Agriculture 5.0 for the 21st Century

With revolutionary tools and automated management systems, farmers can monitor crops, modify planting, and cut production costs, offering innovative technologies that help the farmer pinpoint and understand the number of resources (such as fertilizer, pesticides, and irrigation) critical in each farm area. To comprehend the impact of Industry 4.0 in agriculture, one needs to examine what Industry 4.0 applications are used in agriculture.

Artificial intelligence (AI)

AI in the industry aids machines to amass data, evaluate situations, and offer real-time understanding. On the farm, AI helps improve harvest quality, detect pests and diseases in plants, and regulate what herbicide should be used in every region at any given time. It also allows advanced farming practices like vertical agriculture, a technologically advanced farming system that maximizes resources and increases food production on smaller fields [3].

Sensors

Sensors are essentially one's extended range of vision for data collection to know what is going on both above and below ground. Sensors can sense when crops require irrigation, govern if additional downforce is needed, and instruct what chemicals need to be applied and where. Their capability to measure wind speed, spray pressure and flow, and terrain fluctuations gives the farmer an accurate picture of every corner of their farm. This helps the farm make accurate informed decisions [3].

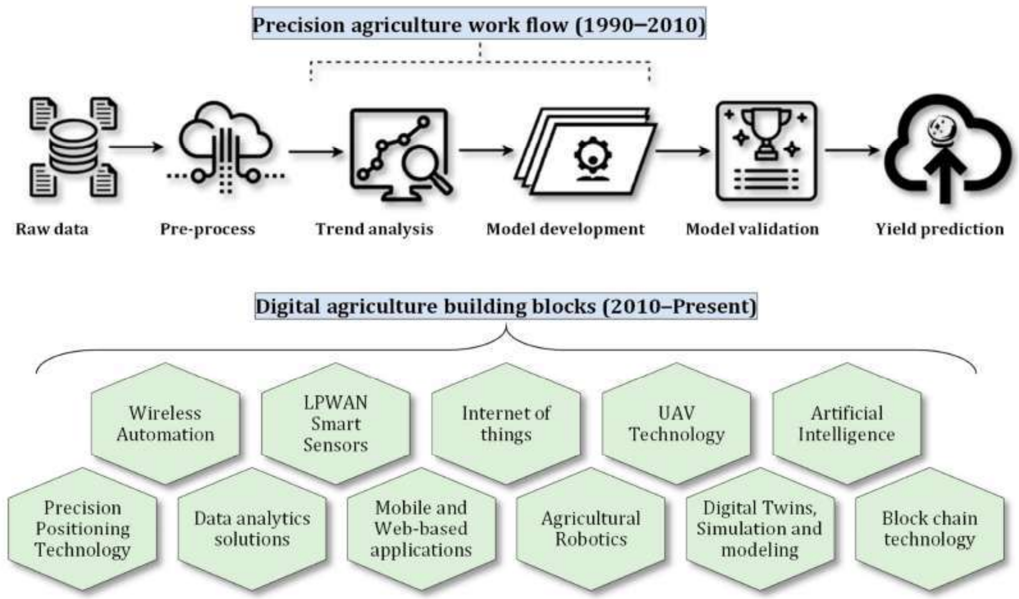

Figure 1A comparison between building blocks of precision agriculture and digital agriculture
Source: https://www.mdpi.com/2071-1050/15/6/5325

Robots and Drones

Farms use drones for surveillance, mapping, surveying, and even delivery. In agriculture, drones are able to deliver useful data regarding soil conditions, plant maturity, disease, pests, and more, often in real-time. The data captured by drones can improve decision-making. Robots are used in post-harvest operations as well as allied agricultural activities such as sorting, quality detection, animal and plant health, and so on [4].

Internet of Things (IoT)

IoT refers to a group of connected devices (such as sensors, drones, probes, and more) as well as software, networks, and other technologies. These elements communicate with an internet network to receive and transmit data. This empowers field management systems to connect data garnered in real-time from GPS-equipped drones, satellites, sensors, and other advanced tools. Systems based on IoT can automatically adapt to weather variations and can plan irrigation schedules accordingly [3][4].

Big data and Machine Learning

The capability to collect and analyse big data has played a revolutionary part in almost every field as well as Agriculture. The key is turning that vast amount of big data into actionable data that can be collected from advanced analytics systems to assist farmers in making more informed decisions. Since datasets may originate from different sources, it is key for data to be properly ingested, cleansed, and harmonized using AI and advanced analytics to obtain insights for practical solutions to a farmer's specific challenges. Machine learning can be used in agriculture to forecast soil parameters like organic carbon and moisture content, crop yield prediction, disease and weed identification in crops, and species detection [3][5].

Road Map for Digital Agriculture to Succeed in India in the 21st Century

To comprehend the challenges related to digital agriculture in India, let us study a typical Indian farm and how it equivalences with the typical farm in the US, Australia, and Europe. The average farm size in the US is 179 Hectares (Ha); in Australia, it is 4331 Ha; in Europe, it is 16.1 Ha; while in India, it is 1.0823 Ha. This disproportion in size infers enormous implications for implementing Digital Agriculture in India. It suggests that Digital Agriculture must be tailored to be applicable to Indian small and marginal farms if we need Digital Agriculture to be scalable and accessible to a majority of Indian farms [6].

Thus, for Digital Agriculture to succeed in India the innovations must emphasize on [6]:

Low-cost technology: The income of farms is very low in India, so it is imperative to lower the cost of technology so that it is available and affordable for the smaller farmers.

Easily portable hardware: Plug-and-play hardware that ensures mobility has a better chance of succeeding in India, as farmers often work on lease land and the farms are scattered.

Renting and sharing platforms for agriculture: Due to both small farm plots and limited financial resources, renting, and sharing platforms rather than outright purchases. Agriculture technology startups like EM3 Agri Services and Trringo are already extending their services. The market is still wide open for scaling up with respect to Digital Agriculture.

Policy reorientation towards facilitating Digital Agriculture: There has been a focus on technology from the government side for the welfare of farmers. Various schemes by the government like

'AgriStack' - a collection of technology-based interventions in agriculture. It will create a unified platform for farmers to provide them end-to-end services across the agriculture food value chain [7].

Digital Agriculture Mission: This has been initiated for 2021 -2025 by the government for projects based on new technologies like artificial intelligence, blockchain, remote sensing and GIS technology, use of drones and robots, etc. [8].

Unified Farmer Service Platform (UFSP): UFSP is a combination of Core Infrastructure, Data, Applications, and Tools that enable seamless interoperability of various public and private IT systems across the country's agriculture ecosystem [9].

Integration of Digital Agriculture in Value Chain: There is an emergence of Farmer Produce Organizations (FPOs) across the entire agriculture value chain, that is, inputs and production processes to the post-harvest and value addition, which includes food processing. These FPOs consolidate farmers and their production in addition to the marketing of the produce. Precision agriculture technologies and smart agriculture can be deployed for FPOs because consolidated and, thus, larger lands are available for technology rollout. At the same time, technology turns out to be affordable and broadly accessible through the medium of the FPO for even the small farmers, making a win-win for all stakeholders.

Reorienting extension services: Extension services, and agriculture-related academic institutions need to reorient themselves towards digital agriculture as they are the individuals who interact with farmers to introduce anything new.

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E-Krishi Kendra: Navigating the Digital Frontier with Agriculture Informatics

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Agriculture has long been the backbone of human civilization, providing sustenance and livelihood to billions around the globe. In recent years, the integration of technology and informatics into agriculture, often termed "Agriculture Informatics," has been revolutionizing the way we cultivate, manage, and optimize our agricultural practices. Agriculture Informatics is the integration of agricultural science and information technology. It involves the use of data analysis, digital tools, and advanced technologies to enhance the efficiency and productivity of farming. This integration enables farmers to make informed decisions based on real-time data, leading to better crop yields, reduced resource wastage, and improved overall management. Benefits of Agriculture Informatics are Enhanced Decision Making, Resource Optimization, Precision Agriculture, Early Disease Detection, Supply Chain Efficiency etc. While the potential of agriculture informatics is immense, its implementation comes with challenges such as Access to Technology, Data Privacy Concerns, Skill Gaps, and Initial Costs. Current Trends in Agriculture Informatics include IoT Sensors, Big Data Analytics, Machine Learning, Blockchain. Tools and Technologies are uses in Agriculture Informatics are Drones, Satellite Imagery, Mobile Apps, and Automated Machinery. The future of agriculture informatics is promising such as Predictive Models, Climate Adaptation, Urban Farming, Data Sharing Networks. Agriculture Informatics Applications: Crop Planning, Smart Irrigation, Disease Detection, Market Prediction, Weed Detection, Robotic Harvesting, Real-time Tracking, Market Access, Disaster Preparedness and Crop Management. Agriculture informatics aligns with sustainable farming practices like Reduced Waste, Conservation of Resources, and Biodiversity Preservation.

Data-Driven Agriculture: From Possibility to Achievability

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Introduction

In the ever-evolving landscape of agriculture, the infusion of data-driven methodologies has emerged as a transformative force, leveraging technology, analytics, and comprehensive data collection to revolutionize traditional farming practices. This paradigm shift holds immense potential, promising to elevate agricultural production, profitability, and sustainability through the optimization of crop yields, resource utilization, risk management, and informed decision-making.

Types of Data Crucial for Smallholder Farms:

1. Weather Data:

Smallholder farmers require precise information on temperature, rainfall, humidity, and other meteorological parameters to make informed decisions about irrigation, planting schedules, and crop management.

2. Soil Data:

By leveraging data on soil properties such as nutrient levels, pH, organic matter content, and soil texture, farmers can make informed choices regarding fertilization, soil amendments, and conservation techniques.

3. Market Data:

Access to market information, including prices, demand trends, and consumer preferences, empowers smallholder farmers to make strategic choices about crop selection, harvesting timelines, and effective marketing plans.

Applications of Data-Driven Agriculture:

1. Precision Farming:

Sensors and satellite photography enable precision irrigation and fertilization, providing real-time information on crop health, weather, and soil moisture. This resource-efficient approach contributes to improved crop health, enhanced production, and sustainable agricultural practices.

2. Crop Planning and Management:

Historical data and predictive analytics facilitate informed decisions on crop selection and planting, maximizing yields and aligning with market demand. Data-driven techniques also support crop health monitoring and pest management, minimizing losses and optimizing interventions.

3. Market Intelligence and Value Chain Integration:

Real-time market information empowers farmers to make educated pricing and market decisions, while digital platforms facilitate direct communication with buyers. Integration into online marketplaces enhances supply chain management, sets fair prices, and increases market transparency, ultimately benefiting smallholder farmers.

4. Climate Resilience and Risk Management:

Climate data analysis enables farmers to anticipate weather changes, adopt climate-smart practices, and cultivate resilient crop varieties. Early warning systems and data-driven insurance options offer effective risk management tools, providing timely alerts and coverage for potential losses.

Challenges and Considerations:

1. Data Privacy and Security Concerns:

The collection and management of agricultural data raise concerns about privacy and security. It is imperative for farmers to have control over their data, necessitating robust precautions to prevent misuse or unauthorized access.

2. Infrastructure and Connectivity Limitations:

Limited infrastructure and connectivity in rural areas pose challenges in data gathering, transmission, and analysis. Innovative solutions, such as offline data collection and low-bandwidth applications, become essential in overcoming these limitations.

3. Ensuring Inclusivity and Addressing the Digital Divide:

Closing the digital divide is crucial for inclusive data-driven agriculture. Efforts should be directed towards providing smallholder farmers with technology, internet connectivity, and training, ensuring equitable access to transformative solutions.

In conclusion, the integration of data-driven approaches in agriculture holds the promise of a sustainable and prosperous future for smallholder farmers, provided challenges are addressed collaboratively, and inclusivity remains at the forefront of technological advancements.

Information Technology Application for Assessment of Physiological and Postural Ergonomics in Agricultural activities

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Ergonomics (also known as Human Engineering, Human Factors or Human Ergology) is the scientific study of relationship between man and his working environment. The term environment includes tools, materials and method of work, ambient conditions and physical environment in which the work is carried out, and also the organizational factors.

Agricultural Ergonomics as Human Engineering is the scientific study of relationship between work, worker and working environment which deals with the Physiological and posture of worker; tools, materials and method of task; ambient conditions and physical environment. Agriculture is one of the most hazardous occupations as it is very much oriented towards manual labor. Agricultural workers are exposed to tremendous hazard that are potentially harmful to their health and well-being which may develop physiological hazards like bruises and postural problems as musculoskeletal disorders (MSDs) in different parts of the body, especially low and upper back pain, during different agricultural activities. The physical demand of the farm work which ranges from moderate to heavy, often includes climbing, standing, squatting, bending and reaching, carrying heavy loads and working for long hours may bring certain hazards to a person. Exposure to different environmental conditions, dusts, gases, noise, chemicals etc. and inadvertent neglect of ergonomical aspects in the design of equipment, workplace or work systems may result in many accidents and occupational health problems.

Agricultural sector in particular farm mechanization and ergonomics aspects are embracing with different Decision Support System (DSS), Mobile App and other Information Technology tools which are being utilized to promote, test, analyze and validate the agricultural machinery in relation to hazards identification and potential solution to combat drudgery.

Keeping in view to reduce the drudgery, innovative IT tools have been developed based on various Ergonomics techniques and parameters i.e (i) Rapid Upper Limb Assessment (RULA)

RULA techniques, (ii) Rapid Entire Body Assessment (REBA), (iii) Human Physical Drudgery Index (HPDI), Ergonomics parameters and also developed mobile app for Nutrition and Health Assessment.

These IT tools help in recording, calculating and decision making after evaluating workers/agricultural activities. These web-based tools record and retrieve the information on various physiological ergonomics parameters of the workers viz. BMI, heart rate; blood pressure; oxygen saturation, blood lactate concentration etc and generate the information on energy expenditure rate of activity performed by worker; total cardiac cost of work; physiological cost of work; postural assessment through rapid entire body assessment and assess and validate the developed farm machineries available. Thus the effective assessment and feedback mechanism through these tools enhances the functional linkage between the clientele, technologies and the development agencies which may help in drudgery reduction.

Keywords: *Ergonomics, drudgery, decision support system, HPDI, RULA, REBA.*

Digital Innovations in Agriculture

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Digital innovations in agriculture have revolutionized traditional farming practices, offering unprecedented opportunities to enhance efficiency, productivity, and sustainability. Technologies such as precision agriculture, the Internet of Things (IoT), and artificial intelligence are being leveraged to collect and analyse real-time data on weather, soil conditions, and crop health. This information enables farmers to make informed decisions, optimize resource use, and minimize environmental impact.

Additionally, the adoption of automated machinery, drones, and robotics has streamlined labour-intensive tasks, leading to increased operational efficiency. Smart farming solutions empower farmers to remotely monitor and control equipment, irrigation systems, and crop conditions, facilitating proactive management and reducing the reliance on manual labour.

Furthermore, digital platforms and mobile applications provide farmers with access to market information, financial services, and agronomic advice, fostering connectivity within the agricultural ecosystem. These innovations contribute to bridging information gaps, improving market access, and empowering farmers to make more informed decisions. The presented paper will discuss some of these innovations prevalent in Indian Agriculture.

Keywords: *Digital transformations, Agricultural informatics, mobile applications*

TS 7: Translational-Omics Research

INVITED TALK

Genome Analysis for the Identification of useful Genes

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The recent developments in the field of genomics have led to the accumulation of vast amount of complete genome sequence data of many plant species. Rice was the first crop plant having its genome sequenced in 2005 followed by draft genomes available for many crops. Such type of genome sequencing efforts helps in the generation of large amounts of genomics resources which are used in functional and comparative genomics. The rice crop with its 389 MB genome sequence has been subjected to various studies by utilizing its sequence data. India, one of the members of International Rice Genome Sequencing Project (IRGSP) has sequenced the long arm of 11th chromosome between 57.3-84.3 cM. Subsequently, we decoded complete genomes of tomato, pigeonpea, mango, Guar,Tea, wheat, Lathyrus Magnaporthe and Puccinia spp. The availability of rice genome sequence has enhanced the development of informative molecular markers and identification and cloning of novel genes. Rice is one of the most important food security crops of India contributing about 40% of the food grain production of the country. Rice is affected by many pathogens of which a fungal pathogen Magnaporthe oryze causing rice blast is one of the important diseases of rice. We identified disease resistance and defence response genes in the rice genome. We found that chromosome 11 of rice is rich in resistance genes which can be isolated by utilizing molecular biology approaches. M. oryzae - rice is a typical gene- for- gene pathosystem, in which resistance gene product interact with the avirulence (Avr) gene product from the pathogen, leading to activation of defence mechanism resulting in resistance phenotype in the host. To understand the molecular basis of rice- M. oryzae interaction, the whole genome of an avirulent strain of M. oryzae was decoded in our lab to identify a candidate Avr-Pi54 gene. Using protein modelling and protein-protein interaction using in silico and in vivo analyses, we showed physical interaction between Pi54 and Avr-Pi54 proteins leading to hypersensitive response, thus proving the molecular basis of host –pathogen interaction.

Genomic selection strategies for main and ratoon crops early in Louisiana sugarcane variety development program

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Sugarcane is an important industrial crop for food and biofuel industries worldwide. Genetic improvement of sugarcane has been slow compared to other crops due to the complexity of its genome, long breeding cycle length, lack of reliable markers for marker-assisted selection, etc. The productivity of sugarcane in Louisiana has doubled during the last 50 years, however, the rate of genetic gain has plateaued in recent years. Genomic selection (GS) is a promising tool in crop breeding to increase selection efficiency and intensity, reduce breeding cycle, and thereby genetic gain. GS also provides breeders with an opportunity to use historical, (often)unbalanced data of the reference population (RP) to predict the performance of new progeny early in the breeding cycle. We assessed the accuracy of sugarcane genotypes (testing population) for cane and sugar yield traits within and across different stages of our sugarcane variety development program using 20,451 SNPs with 20 genomic prediction models. The datasets comprised of 11 years (2010-2021) of phenotype data of the RP representing various but consistent locations, which were further clustered based on soil and crop types. Based on the genomic estimated breeding values, traits such as sucrose content and stalk weight had higher prediction accuracies at 0.44 and 0.42, respectively. As expected, traits with higher heritability were predicted with higher accuracy. Interestingly, non-parametric machine models such as random forest (RF) and support vector machine (SVM) outperformed other genomic selection methods. The results will be discussed in detail relating to the effect of models, optimal marker density, fixed effect markers etc.

Artificial Intelligence tools in Gene based Evolutionary Studies

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Artificial Intelligence, a subset of computer science, empowers machines to perform tasks traditionally requiring human intelligence. Within the realm of genomic data, AI tools, such as Variant calling and genomic analysis tools like GATK (Genome Analysis Toolkit) and Samtools, play a crucial role in unravelling complexities. These tools help in identifying genetic variations, including single nucleotide polymorphisms and indels (insertion and deletions), ultimately explaining the biological diversity. To understand high volumes of genomic sequence data specifically and sensitively, various algorithms are used including, likelihood based, Expectation-Maximization (EM) algorithm, and mpileup that involves the pileup of reads at each genomic position to identify different genetic variants. Machine learning tools such as Admixture and STRUCTURE allows the researchers to explain the nature of sequence variation in different population groups and individual ancestry. Machine learning tools use different algorithms including regression models (predict the missing values based on their relationship with observed values in the data); K-nearest neighbors (identifies the k most similar data points to the missing value and uses their average to fill it in); Convolutional neural networks (capture complex patterns in the data and predict missing values with high accuracy). These tools allow the estimation of ancestry coefficients simultaneously with maximum likelihood estimation of allele frequencies. To analyse and interpret the genomic data, tools like RAxML (Randomized Axelerated Maximum Likelihood), IQ Tree, and BEAST (Bayesian Evolutionary Analysis by Sampling Trees) are used. These tools enable researchers to infer evolutionary relationship among species by analyzing the molecular sequence. Evolutionary dynamics and selection analysis tools such as PAML (Phylogenetic Analysis by Maximum Likelihood) and EasyCodeML provide means to determine the evolutionary rates, selection pressure and to explore the adaptive evolution of genes. These tools use Bayes Empirical Bayes (BEB) approach that calculate ω (dN/dS) ratios to determine whether codon has undergone positive selection or not. These tools have been used for determining the sites undergoing substitutions mutations in the selection region in human BMP4 and BMP5 genes, possibly causing prostate cancer. Positive selection pressure in the AQP genes in cetartiodactyla (dolphins) suggests the adaptation of these animals in harsh environmental conditions.

Genome Editing for Improving Yield and Climate Resilience in Rice

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Rice is the major food crop, and contributes to about 40% of the food grain production of India. India remains the world's largest rice exporter for more than a decade with an annual export of 17.8 million tonnes of Non-Basmati Rice worth Rs. 51,088.72 Crores/USD 6,355.74 Million during the year 2022-23. Therefore, rice cultivation is important not only for food and livelihood security of India but also for the food security of importing countries. Rice uses more than 50% of the irrigation water is it has a low WUE. Rice grown in rainfed ecosystems (38% of the total rice grown area) suffers from drought stress. Dwindling fresh water scarcity and global climate change demands development of high WUE and drought tolerant rice varieties with high yield. Therefore, our lab is working on development of climate resilient rice using CRISPR-Cas9 mediated editing of several target genes including DROUGHT AND SALT TOLERANCE (DST), Protein Phosphatase 2C (PP2Cs) Clade A group, MIR169, Farnesyl Transferase (FTA) and Phytomelatonin Receptor (PMTR). We developed four different mutant alleles of dst gene in mega rice cv. MTU1010, and identified two lines free of introduced exogenous DNA. These dst mutants exhibited reduced stomatal density, at least, in part due to downregulation of stomatal developmental genes. The dst mutants exhibited tolerance to osmotic and salt stress in seedling stage in hydroponics study and adult plant stage pot culture studies. These mutants produced significantly higher grain yield under non-stress and drought stress conditions under field conditions in a transgenic net house. Mutants with high yield and stress tolerance developed in this study will be useful to release as variety and as a genetic stock for introgression of dst mutations in other indica varieties for genetic improvement in yield and climate resilience.

Keywords: *Abiotic stress tolerance, CRISPR-Cas, Transcriptome, Stomatal development, WUE.*

Genome Editing in Vegtable Crops for Improvement: Present Status and Future Prospects

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Abstract

Plant diseases have an adverse effect on the quality and quantity of vegetables, resulting in one of the most significant barriers to crop production. As vegetables are the primary source of nutrition in the diet, disease-related losses pose a substantial threat to nutritional security. This demands focused breeding initiatives to create disease-resistant vegetable varieties. Aside from molecular breeding, the recently developed genome editing technique employing CRISPR/Cas9 is the most promising strategy to creating disease resistance in plants. CRISPR/Cas9 is the most efficient and user-friendly genome editing technique currently available. This has resulted in the finding of additional Cas variants and the creation of tools for a variety of applications such as gene knockout, RNA editing, base editing, gene activation, chromosomal engineering, nucleic acid detection, chromatin imaging, and so on. One of the most exciting uses is base editing, which allows for the direct, irreversible conversion of one nucleotide base to another at a specific point in the genome.

After initial demonstration of CRISPR/Cas9 tool for developing virus resistance in plants, it has been successfully utilized in different vegetable crops primarily by targeting the susceptibility genes in plants required for infection and survival of the pathogens. One of the best examples is the knockout of MLO gene causing downy mildew resistance. Resistance against RNA viruses has been developed in cucumber by targeting the eIF4E gene. Most of the work has been carried out in tomato where knockout of genes like MAPK3 and CCD8/MAX1 resulted in resistance against Botrytis cinerea and Phelipanche aegytiaca respectively. In tomato, DMR6 mutant plants can be obtained using CRISPR/Cas9 to develop resistance against, fungal and bacterial diseases. Similarly, knockout of Pectate lyase gene produces firm tomato fruits resistant to grey mold. With CRISPR/Cas tool in the armor, development of disease resistant cultivars is only limited by availability of susceptible genes and regeneration and transformation protocol in a vegetable crop.

Keywords: *CRISPR/Cas9, genome editing, Vegetables, Biotic stresses*

Metagenomics for Aquatic Ecosystem Health Surveillance

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Aquatic ecosystems are vital for global biodiversity and human well-being, yet they face increasing threats due to pollution, climate change, and human activities. Monitoring the health of these ecosystems is crucial for effective management and conservation of aquatic biodiversity. Metagenomics, a powerful tool in microbial ecology, has emerged as a valuable approach for assessing and understanding the intricate microbial communities within aquatic environments. This research provides a comprehensive overview of metagenomic applications for monitoring the health of aquatic ecosystems. Metagenomics enables the analysis of microbial diversity, composition, and functional potential in aquatic habitats, offering insights into ecosystem dynamics and responses to environmental stressors. The utility of metagenomics is to characterize biodiversity, identify indicator species, and detect shifts in microbial community structures as early warning signs of ecosystem disturbances. Moreover, the identification of microbial biomarkers and functional genes associated with pollutants, pathogens, and ecosystem functioning aids in assessing water quality and ecosystem health. The role of metagenomics in understanding microbial community responses to environmental changes, such as temperature fluctuations, nutrient imbalances, and contaminant exposure. The ability to predict ecosystem functioning and resilience through metagenomic analyses supports adaptive management strategies and restoration efforts. Furthermore, metagenomics study can help in guiding bioremediation approaches and the restoration of degraded aquatic habitats by harnessing the functional capabilities of microbial communities. Metagenomics offers a powerful and integrative approach to holistic assessment, monitoring, and management of aquatic ecosystem health. Continued advancements in metagenomic technologies and their application in environmental monitoring hold immense promise for ensuring the conservation and sustainability of these critical ecosystems in the face of ongoing environmental challenges.

Prediction of enzymes involved in bioremediation using metagenomics data

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Growing use of chemicals, heavy metals, synthetic colours, and pesticides by industries emit dangerous chemicals into water and affect living organisms by seriously impairing their health. To remove these organic and inorganic pollutants from wastewater, numerous approaches have been used. Among these techniques, bio-remediation is the most appealing technique because it is economical, sustainable, and environmentally beneficial. Utilizing bio-based remediation techniques has advantages over traditional techniques. For the removal of dyes, heavy metals, hazardous industrial effluents, fertilizers/ pesticides, air pollutants and nuclear waste, a variety of enzymes and microbes are widely utilized. The identification of bio-remediating enzymes has made considerable use of metagenomics and several NGS technologies. Metagenomic analysis is regarded as a potent tool for examining the variety of bacteria present in environmental samples without the need for any cultural methods. The world of microbes has radically transformed due to metagenomics. It has given analysts of microbial genes and metabolites new perspectives. It provides an excellent method for describing the genes, proteins, abundance, and metabolic pathways of bacteria that may be investigated for the bioremediation of different pollutants.

In this study, identification of dye, hydrocarbon, and plastics degrading enzymes was done utilizing metagenomics data from four different sites along the Ganga i.e. Nawabganj and Jajmau in Uttar Pradesh and below Farakka bridge and Paharghati in West Bengal. A tool called RemeDB was utilized to identify these enzymes. To identify the abundance of these enzymes, a pipeline called MG-RAST pipeline (https://www.mg-rast.org/) was used. It was also attempted to find out the locations that are less or more polluted. Metabolic pathways of these enzymes were also identified using KEGG pathways (https://www.kegg.jp/kegg/pathway.html). A web-based search tool that lists all the enzymes, name of the organism, the pollutants they degrade and its percentage has also been developed.

Keywords: *Metagenomics, abundance, plastic degrading enzyme, pipeline, hydrocarbon, dye*

Omics Research in the era of Artificial Intelligence

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Past decades have seen a substantial growth in generation of huge volumes of biological data and availability of computational tools for its analysis and interpretation. Genomics, metagenomics, transcriptomics and proteomics are among major areas along with other sub-areas as databases and algorithms. Management of biological data and integration of multi-omics data requires the power of latest AI based techniques for future innovations and discoveries. Traditional analysis methods augmented with latest machine learning, deep learning and big data technologies for handling large scale biological data may drive this field further. Keeping this perception, some applications in applying machine learning and deep learning techniques in the area of bioinformatics will be discussed.

Keywords: *Genomics, Metagenomics, Deep Learning, Deep Clustering*

ABSTRACT

Hotspot detection and analysis of Brown Spot in rice using KCC data

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Abstract

Rice crop accounts for nearly a third of the total area under food grains in India and is the staple food for a significant portion of the world's population. Widely varying factors influence the growth of rice in different rice growing areas and render the crop susceptible to various pathogenic and non-pathogenic diseases, resulting in extensive damage of grain and straw yield. The annual worldwide yield loss of 5% is attributed to brown spot, caused by *Helminthosporium oryzae*. Fields severely impacted by the disease can experience a staggering 45% reduction in yield. This study delves to mitigate the incidence of the disease and outlines prospective measures for developing an effective disease management protocol in the near future. The goal of this study is to explore data

from a farmers' helpline center as a new medium to gain hidden insights of brown spot. The dataset used in this study is collected from the "Kisan Call Center", a farmers' helpline center. The article demonstrates the Spatio-temporal profile of brown spot First, the framework extracts and clusters the precise geographical locations of farmers calling for brown spot help. Then the hotspot for brown spot is found. Next, the temporal modeling of the problem helps to extract the critical dates corresponding to the crop disease spread. The extracted inference reveals many hidden patterns of the brown spot disease spread and finds the potential hotspot of the same.

Keywords: *Brown spot, KCC, Spatio-temporal analysis, hotspot, Data mining in agriculture*

Unraveling biological complexity: Principal component analysis in Omics symphony

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Abstract

Principal Component Analysis (PCA), PLS, and PCA-DA variants are some of the multivariate analysis approaches that have shown useful for identifying patterns in the omics data. These patterns occasionally include identifying outliers that tainted the data and may be eliminated. PCA enables the identification of the variables most responsible for the association found between the research samples and quantifies the main sources of variability in the data. Moreover, surrogate variable analysis (SVA) and EigenMS techniques can identify undesired sources of variability like batch effects and partially fix them. However, using PCA to "omics" data has certain drawbacks. These restrictions stem from the wide range of pre- and post-processing data methods available and the technical challenge of displaying all the data graphically. Using Grand Tour and 2D Tour, ggobi and rggobi enable the display of quite significant amounts of data while displaying dynamic projections with the ability to color and glyph points based on many criteria (brushing). PCA is an invaluable tool in the basic examination of the data and in filtering or screening them according to noise, outliers and batch effects before utilizing other multivariate tools such as classification and clustering. Future biologists should be

exposed to the theory and applicability of these techniques through a suitable educational program at institutions.

The Halophile Protein Database 2.0: A Comprehensive Resource of Chemical and Physical Properties of Halophilic Proteins

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Abstract

Halophiles are one of the oldest microorganisms on the earth that have exhibited adaptations to different salt concentrations, namely, extreme, moderate and low. These adaptations may occur due to modifications in protein structures and alterations in different cell organelles. Proteins play important role in facilitating the adaptation of halophilic organisms to different salinity conditions. An advance Halophile Protein Database 2.0 (HProtDB 2.0) has been developed that serves as a comprehensive resource of chemical and physical properties of halophilic proteins. These proteins may have been involved in adaptation of halophilic organisms (archaea/ bacteria) in saline conditions. The database includes the diverse physico-chemical properties such as molecular weight, theoretical pI, amino acid composition, atomic composition, instability index, aliphatic index, extinction coefficients, estimated half-life, grand average of hydropathicity index, etc. These physiochemical properties are crucial for understanding the structural and functional role of the halophilic proteins. The earlier version of database “HProtDB” contained the information related to 59897 protein sequences from 21 strains of halophilic archaea/ bacteria. However, the advanced version of database “HProtDB 2.0” encompasses information on 777988 protein sequences from additional 33 strains (total 54 strains) of halophilic archaea/ bacteria. The three-tier web architecture has been used to develop the database. The web resource involves HTML, CSS, and JavaScript for the front-end client-side user interface, PHP for server-side scripting and database connection, and MySQL as the back-end database. This database will serve as valuable tool for researchers seeking information on the characteristics and features of proteins adapted to salt conditions.

Keywords: *Amino acid composition, atomic composition, peptides, proteins, physico-chemical properties*

Picro-DB is an extensive genomic resource portal dedicated to Picrorhiza kurroa, a medicinal plant

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Abstract

Picro-DB serves as a pivotal repository hosting the genome of Picrorhiza kurroa, a medicinal plant belonging to the Scrophulariaceae family. Originating from the Picrorhiza genome sequencing initiative, this database functions as an inclusive portal for Picrorhiza kurroa, offering open public access. Built on the foundation of the de novo assembled draft genome of P. kurroa, it stands as a groundbreaking reference for genomic and molecular investigations related to this plant. Notably, Picro-DB holds the distinction of being the first genomic sequencing resource for the Scrophulariaceae family. Enhancing its usability, Picro-DB provides essential tools such as BLAST and BOWTIE mapping, facilitating sequence similarity searches and mapping functions to strengthen genomic analyses. During its development, Picro-DB incorporates interactive elements like radial plots, circle plots, and krona plots, ensuring user-friendly navigation and understanding. With an integrated genome browser and advanced visualization capabilities, Picro-DB empowers users to explore diverse genomic components, including genes, repeats, miRNAs, transcription factors, and the reference genome. By making the P. kurroa reference genome accessible online, this resource streamlines the acquisition of comprehensive insights into the Picrorhiza kurroa genome, promoting conservation efforts and broader botanical investigations. (Web portal URL : https://scbb.ihbt.res.in/picro-db/).

Keywords: *BLAST, BOWTIE mapping, De novo assembled draft genome, Integrated genome browser,*

Phylogenetic Relationships and Evolution of the E3 (Phytochrome A3) Proteins in Soya bean (Glycine max)

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Abstract

To know the origins of any living organism and to know the process of how they came to be as they are today requiring a deep study of their evolutionary history and requires tracking of the changes conferred by such evolution. In this aspect, Soybean has been orphaned out owing to the least efforts made in exploration, well established quality research and quality improvement. In this light, this study deciphers the evolutionary relationships between different species of plants in terms of divergence/relatedness of E3 (phytochrome A-3-like) protein among such individuals. Phylogenetic analysis of E3 (PhyA3) protein sequence from different members revealed that Glycine max E3 (Phy A3) TFL nucleotide was found to share the closest ancestral relatedness to Glycine soja PhyA2. Glycine max E3 (Phy A3) depicted to share common evolutionary relationship with Lupinus angustifolius.

Keywords: *Phytochrome PHYA3, MEGA, Blastn and Phylogenetic analysis*

TS 8: Aligning Statistical Sciences in NEP 2020

INVITED TALK

Redesigning Agriculture Higher Education with Digital Interventions in sync with NEP 2020

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India’s New Education Policy was released in July 2020. The policy is an important document, the recommendations of which have provided insights into the expected growth trajectory of the Indian education system, as envisioned by the government and its people. The most prominent theme that emerges from this policy is the importance of developing a contemporary education system that is in-tune with ever changing macro realities. To this end, the new education system is envisaged as one drawing, in equal parts, from current research, practice and technology trends.

Agricultural higher education is undergoing a digital transformation across India. Both offline and online education modes have grown in leaps and bounds in the past few years. The COVID 19 pandemic has further accelerated the transition to a more fluid, student centric teaching learning methodology. The use of new technology platforms and technology-aided learning tools is transforming the traditional teacher-class based teaching to digital learning in agricultural universities.

India's National Education Policy (NEP) 2020 has brought about significant reforms and changes to the educational system, with a particular focus on digital learning. However, there are a number of obstacles that must be overcome when implementing ICT in remote areas, including poor internet connectivity, limited infrastructure, and restricted access to devices. India leads the world in the IT industry as well as other cutting-edge fields like ICT in education.

Digital learning is going to be a big part of the educational system's empowerment and outcomes. Digital learning is the future of learning in India-home to one-sixth of the world's population. India is going to have the largest number of global youth population by 2030, which necessitates the need to harness the demographic dividend by use and infusion of digital education solutions in higher educational institutions to improve their skills and knowledge.

In this article, we attempt at understanding the core recommendations of the NEP 2020 with respect to higher education in general and agricultural higher education in particular. Additionally, we highlight some of the key initiatives undertaken by the Indian Council of Agricultural Research (ICAR) – Indian Agricultural Statistical Research Institute (IASRI) that, in principle, align with the recommendations of the NEP 2020.

Online and Digital Agricultural Education: Ensuring Equitable Use of Technology

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The evolution of digital education has been a remarkable journey. From its humble beginnings as a mere concept, it has rapidly transformed into a global phenomenon that has revolutionized the way knowledge is imparted and acquired. With the advent of advanced technologies, digital education has transcended barriers of time and resources, offering learners access to a vast repository of content at their fingertips. The integration of multimedia, interactive platforms, and personalized learning tools has enhanced engagement and fostered self-paced learning. As digital education continues to evolve, it holds the promise of empowering learners in various fields, providing opportunities for lifelong learning and bridging educational gaps. Agriculture, on the other hand is an age-old field intertwined with the very sustenance of humanity, holds the key to feeding and nurturing our growing global population. With a rapidly growing population and increasing demands on agricultural productivity, it is crucial to equip individuals with the knowledge and skills necessary to navigate this complex field. As the world evolves, the methods of imparting agricultural education must also evolve. Digital Content development for Agricultural Education and making it freely accessible online is a unique initiative, revolutionizing education by offering accessible and flexible learning opportunities anytime, anywhere. Its comprehensive collection spans various disciplines ensuring a holistic and enriching educational experience for students, researchers, and faculty alike. The E-content is meticulously created and reviewed by prestigious faculty of Agricultural Universities and is aligned with the curriculum, ensuring a comprehensive and cohesive educational experience.

Keywords: *Digital Content, E-Course, Agricultural Education, Online Education*

TS 9: Current Status and Challenges in Official and Horticultural Statistics

INVITED TALK

Machine Learning Techniques for Outlier Detection in Horticultural Data

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This study delves into the comprehensive comparison of outlier detection algorithms, including Elliptical Envelope, Isolation Forest, One Class SVM, and Local Outlier Factor, utilizing data from Gala Red Lum apples cultivated in a High-Density Plantation. The assessment involves evaluating yield and Trunk Cross-sectional Area (TCA) data for both univariate and bivariate cases. The study reveals that the Elliptical Envelope algorithm demonstrates a marginal superiority across various metrics. Significantly, One Class SVM encounters challenges in univariate scenarios but excels in bivariate case. Upon the removal of outliers, notable improvements in data statistics and the symmetry of distribution are observed. Bivariate case analysis emerges as the preferred approach, showcasing higher R^2 and lower variance, Coefficient of Variation, Mean Squared Error (MSE), and Mean Absolute Percentage Error (MAPE). The findings offer crucial insights for achieving precise results in horticultural datasets, underscoring the significance of the Elliptical Envelope algorithm.

Keywords: *Elliptical Algorithm, Isolation Forest, Local Outlier Factor, One Class SVM, Outlier*

Statistics on Area and Production of Horticulture Crops in India

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The Horticulture Statistics Division (HSD) in the Department of Agriculture and Farmers Welfare compiles and publishes 'Estimates on Area and Production of Horticulture Crops' in the country periodically. For every agricultural year, before the estimates are finalised, three advance estimates are released as per set timelines. These estimates are based on the crop-wise data furnished by Horticulture Departments of respective States and UTs and other National Level Source Agencies such as Directorate of Arecanut and Spices Development (DASD), Directorate of Cashewnut and Cocoa

Development (DCCD), National Bee Board (NBB) and Directorate of Mushroom Research (DMR).

In the earlier years, the data compiled by the Horticulture Statistics Division used to be published by the National Horticulture Board(NHB). However, from 2012 onwards, the release and publication of the estimates is also done within the Department.

Compilation of Area and Production estimates of Horticulture Crops

A web portal namely "Horticulture Area Production Information System (HAPIS) has been created by this ministry to upload district-wise /crop-wise area and production data in respect of 130 plus horticulture crops under the broad categories such as Fruits, Vegetables, Plantation Crops, Spices, Aromatic & Medicinal Plants and Honey. The HAPIS portal system has significantly improved the coverage, quality and also reduced the time lag in releasing the timely estimates. The data is being uploaded regularly by each State/UT /National Level Source Agencies as per standard guidelines. The DA&FW publishes State/UT-wise estimates separately for 88 crops in these categories.

DA&FW also publishes an Annual publication namely "Horticulture Statistics at a Glance" providing a comprehensive picture of the horticulture sector of the Country with time-series data on important parameters such as, area, production, value of output, storage and processing infrastructure, market arrival, prices, import & export, global production, etc. The latest publication is released in December 2023 covering crop-wise data up to 2020-21.

Weekly Monitoring on Tomato, Onion and Potato (TOP) crops for major producing States:

As per the recent government directives, HSD undertake a special weekly monitoring system for three important vegetable crops such as Tomato, Onion and Potato (TOP Crops), where the season-wise progress in sowing, area/production damage due to various climatic factors, estimated production, monthly harvest, wholesale mandi prices etc. are monitored for the major producing States. The monitoring of crop status includes regular meeting through VC and physical mode with the major state producing states, physical inspection of crops by central agencies. The dataset thus generated is being used for input for farmer support/inflation control measures by the Government and various user agencies/ stake holders.

Other initiatives taken up for improvement of estimates

HSD has taken up initiatives for standardisation on methodology of estimation in specific categories of horticulture crops by engaging with the Stake holders in each of these categories with the help of Central level agencies. Periodic ground-truthing exercises through field visits, engaging other agencies for important crops. Area/Sector

Specific workshops are being conducted to strengthen the traditional method of estimations. Remote sensing based estimates are also being attempted with the help of MNCFC for TOP crops. A sample survey based methodology for crop estimation for fruits and vegetables was developed with the help of IASRI and was made available to the States/UTs for adoption.

Issues and Challenges

No standard methodology is adopted uniformly in all States/UTs. Except for major crops, Current estimates are to an extent based on subjective reports from the field Lack of any reliable alternate estimates make data triangulation difficult. The **large** number of crops under Horticulture and its wide variation across the States make it difficult to adopt a uniform methodology. However, the growing importance of Horticulture in terms of its share in GDP, profitability to farmers and focus of crop diversification activities calls for more reliable estimates of horticulture area and production. At present, there is no separate scheme for providing support to States/UTs for the collection and compilation of Horticulture Statistics. The Digital crop survey, newly initiated by DA&FW, is expected to cover this aspect.

Generation of Horticultural Statistics in India: Methodological Aspects, Challenges and Road Ahead

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Horticulture holds a significant position in India's agricultural landscape, contributing substantially to the economy and ensuring food security. The accurate generation of horticultural statistics is crucial for informed decision-making, policy formulation, and sustainable development in this sector. The ICAR-Indian Agricultural Statistics Research Institute (ICAR-IASRI), New Delhi plays a pivotal role in shaping methodological approaches, addressing challenges, and outlining a roadmap for the future in the generation of horticultural statistics. The estimates of area and production of important fruits and vegetables were obtained till 2012-13 under the scheme on Crop Estimation Survey on Fruits and Vegetables (CES-F&V) using the methodology earlier developed by ICAR-IASRI. The National Statistical Commission (NSC) observed that the methodology provides reliable estimates but is complex and not cost effective and suggested to review and develop an alternative methodology for estimating the production of horticultural crops taking into account information flowing from all sources including market arrivals, exports and growers associations. In view of NSC recommendation a project entitled “Pilot study to develop an alternative methodology for estimation of area and production of horticultural crops” funded by Central Statistics Office (CSO), Ministry of Statistics and Programme Implementation (MoSPI), Govt. of India was undertaken by ICAR-IASRI in two states namely, Maharashtra and Himachal Pradesh covering major fruits and vegetables in major fruit and vegetable growing districts. One important recommendation of this study was to validate and test the developed methodology before its implementation at large scale.

In view of the above recommendation, another project entitled "Study to test the developed alternative methodology for estimation of area and production of horticultural crops: IASRI Component of CHAMAN Programme under MIDH" was approved by the then Department of Agriculture & Cooperation (DAC), Ministry of Agriculture, Govt. of India as IASRI component of the Coordinated programme on Horticulture Assessment and Management using Geo-informatics (CHAMAN) project under Mission for Integrated Development of Horticulture (MIDH). The ICAR-IASRI was declared as National Level Agency (NLA) under MIDH. The alternative sampling methodology developed by ICAR-IASRI during the previous study was modified and domain estimation approach was used in development of estimation procedure as per the proposed sampling design. The study was carried out in six states namely, Maharashtra, Andhra Pradesh, Tamil Nadu, Himachal Pradesh Haryana and Madhya Pradesh to test and validate the developed sampling methodology.

The developed methodology was efficient, simple, less time consuming and cost effective. Under this sampling methodology, sample survey procedures was simplified and sample size was reduced significantly than the existing methodology. The sampling design adopted for the survey is stratified multistage random sampling considering for high and low productive districts in a state. It is worth mentioning that based on the present study the recommended sample size i.e. no. of villages to be selected from a district is 80. Hence, there is a decrease in sample size i.e. from 150-200 villages per district (as per CESF&V scheme) to 80 villages per district. The generated estimates of area and production of fruits and vegetables were compared with the area and production figures published by DACFW. The developed methodology for estimating area and production of fruits and vegetables has been appreciated by several honorable dignitaries from Govt. of India. The details of the sampling methodology are quoted in “Horticulture Statistics at a Glance 2018” published by DACFW, MoAFW, Govt. of India. The methodology has been developed under CHAMAN by ICAR-IASRI has been quoted in the Chapter-8 on horticultural crops in “Handbook on Crop Statistics” published by FAO of the United Nations in December 2018.

After validation of the developed methodology, it was expected that the developed methodology will be adopted in all the states of the country in future by Division of Horticulture, Department of Agriculture, Cooperation & Farmers Welfare (DACFW), Ministry of Agriculture & Farmers Welfare (MoAFW), Govt. of India. Modification and finalization of EFC/SFC was done for the proposed creation of “Scheme for Improvement of Horticulture Statistics” prepared by the Division of Horticulture, DACFW, MoAFW, Govt. of India for rolling out the methodology in all the states of the country. The developed methodology is being implemented in Haryana State since 2019-2020 onwards by the Directorate of Horticulture, Panchkula, Haryana from State Govt. own fund and technical guidance for implementation of the methodology is being provided by ICAR-IASRI. The Division of Horticulture, DACFW, MoAFW, Govt. of India has recommended to implement the methodology in five southern states of the country and technical guidance for implementation of the methodology will be provided by ICAR-IASRI.

Generation of horticultural statistics in India requires a holistic and adaptive approach. Major challenge in generation of horticultural statistics is the timely and accurate reporting of data. Delays in data collection and reporting can impede the effectiveness of policies and interventions. Under the study, primary data was collected using schedules, was entered using the developed Data Entry Software and estimates for surveyed districts were generated using the developed Data Analysis Software. ICAR-IASRI, along with its emphasis on survey methodological aspects, is working on leveraging technology-driven solutions, such as mobile applications and real-time end-to-end solutions for data collection and generation of statistics, to streamline the reporting process and improve the timeliness of horticultural statistics. As the institute continues to innovate and collaborate, the road ahead holds promise for a more accurate, timely, and comprehensive understanding of India's dynamic horticultural sector.

Agri-Business Identification Planning and funding for entrepreneurship Development

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Why horticulture?

- Horticultural crops provide adequate nutrition to the people in their daily diet.
- Higher income per unit area by planting fruit/vegetable/flower crops.

- Higher production per unit due to intensive farming and multi-level system
- Creation of new employment opportunities in horticulture sector through nursery, processing unit, value addition etc.
- Reduce farming costs and contamination by efficient use of water and fertilizers through micro-irrigation and mulching.
- Biennial income from production of Vegetables / Precious Flowers in controlled environment by Polyhouse / Shadenet House.
- Raising quality seedlings in hi-tech nurseries / plug nurseries.
- Disease from tissue culture – production of pest free planting materials
- Making infertile paddies fertile by renovating Junivadi
- Speeding up farm operations by reducing labor costs through farm mechanization
- Export oriented production with post-harvest management and cold chain management
- To be an inspiration to other farmers by benefiting from various schemes of Horticulture Department.
- To promote women empowerment through home garden of fruit and vegetable gardens and canning of horticultural produce.
- Income through honey and mushroom production to landless persons

Supportive components of horticulture accounts

Assistance in planting

- 50 to 75% support for plantation of various fruit crops like mango, pomegranate, guava, chiku, lemon, banana, papaya, strawberry, kamalam (dragon fruit), fig, falsa, tissue culture kharek, amla and jambu.
- Subsidy upto 90% of unit cost for planting materials of perennial fruit crops
- Subsidy up to 40 to 75% of the unit cost for planting of hybrid seeds of vegetable crops and support of vining vegetables – Mandap
- Subsidy of 55 to 75% of unit cost for cultivation of flower crops, spice crops, medicinal and aromatic crops.
- According to caste as well as according to Free hybrid seeds of vegetable crops along with other input kits to Jan Jati farmers
- Fruit Productivity Enhancement Programme: Mango – Guava – Plantain (TSU)
- Coconut plantation area assistance.
- Comprehensive Horticulture Development Programme

Production assistance

- Assistance to renovate / regenerate old gardens

- Support for drip irrigation, water soluble fertilizers, integrated nutrient management, integrated pest management
- Support for plastic mulching, construction of greenhouses, shade net houses and planting of high value flower/vegetable crops.
- Assistance in setting up hi-tech nursery, plug nursery, tissue culture lab, bio control lab
- Assistance for purchase of mini tractor, power tiller, crop protection equipment
- Support for beekeeping, mushroom production
- Self-employment Oriented Horticulture Nursery Development Programme

Activities of Horticulture Department

- On-farm infrastructure program to prevent post-harvest spoilage in horticultural crops
- Guidance on technical operations as well as horticulture crop production through Horticulture District Implementation System / Taluka Horticulture Extension System.
- 23 nurseries of horticulture department are functioning to provide good quality grafts, seedlings and seedlings to the farmers at reasonable prices.
- Farmer training, farmer tours, seminars, workshops, exhibitions as well as skill enhancement training to farm labourers.
- 2 to 5 days training with stipend on value addition of fruit and vegetable crops and home garden kitchen garden for women empowerment
- One day training on urban horticulture for urbanites
- Three days gardening training with garden tools kit and stipend under Urban Green Mission programme.
- Primary processing units are being set up in the districts of Kutch, Jamnagar, Banaskantha, Panchmahal and Navsari in the first phase to be operated through FPOs/cooperative organizations.

To avail the benefits of assistance schemes

To benefit from the support schemes of the Horticulture Department, the farmer has to apply online at https://ikhedut.gujarat.gov. in, take a printout and submit it to the Horticulture Office of the concerned district along with necessary documents.

Time series analysis of area, productivity and prices of Mango in Valsad district, Gujarat

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Mango comprises 75% of total production, with India leading global production. Forecasting mango area, production, and prices is vital for informed decision-making in horticulture, ensuring sustainable growth for farmers. Prices are impacted by cultivated area, yield, and pre/post-harvest practices. Challenges in price fluctuations arise due to seasonality and perishability. This study employs time series intervention modeling to forecast mango area, productivity, and prices, addressing essential aspects for the agricultural and economic well-being of farmers and stakeholders. In this study, simple exponential smoothing (SES) was applied to create forecasting models for mango area and productivity. Exploring different values of alpha (α) under SES, it was observed that values of 0.8 and 0.9 resulted in the minimum Mean Absolute Percentage Error (MAPE) for area (3.11%) and productivity (12.73%), respectively. Additionally, time series ARIMA models were developed to forecast mango prices (Keshar and Alphonso) in Valsad markets, Gujarat. ARIMA (6, 1, 2) and ARIMA (1, 1, 2) were identified as effective models for forecasting Keshar and Alphonso prices in Valsad district.

Keywords: *ARIMA, Mango price, Time Series, Simple exponential smoothing*

ABSTRACT

The Growth Patterns of Key Vegetable Crops in Selected Districts of Gujarat: A Comprehensive Analysis

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Abstract

Following the green revolution, there was a substantial increase in the nation's vegetable production. Given their short cultivation period, high yield, nutritional richness, economic viability, and their potential to generate on- and off-farm employment opportunities, vegetables play a vital role in Indian agriculture and the nation's commitment to ensuring universal access to sufficient nourishment. India, ranking as the second-largest global producer of vegetable crops after China, contributes to 21 percent of the global vegetable production. Gujarat holds the position of the fifth-largest vegetable producer, accounting for 6.7 percent of the total vegetable production. This research aims to scrutinize the growth patterns in the area, production, and productivity of major vegetable crops across specific districts. To execute this study, six distinct vegetable crops (potato, onion, brinjal, okra, tomato, and cucurbits) were chosen based on their production, and five districts were selected for each crop based on their respective cultivation areas. The study utilized district-wise time series data encompassing the period from 2005-06 to 2020-21. Employing the compound annual growth rate and instability index, the research investigated the growth statistics of major vegetable crops. The study revealed that all selected vegetables experienced positive and significant growth rates for area, production, and productivity in Gujarat, with the exception of onion. Onion and tomato exhibited moderate instability in terms of area and production in Gujarat, while potato, brinjal, okra, and cucurbits demonstrated low instability in both area and production. The productivity of all selected vegetable crops showed low instability in Gujarat.

Keywords: *Vegetable Crops, Growth analysis, Compound Annual Growth Rate, Instability Index*

A Comprehensive Study of Growth Statistics in Major Fruit Crops of Gujarat

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Abstract

The horticulture sector is increasingly acknowledged as an emerging industry with the potential to augment farm income, ensure livelihood security, and contribute to foreign exchange earnings through exports. India is widely recognized as a global repository of fruits and vegetables, securing its position as the second-largest fruit producer globally, following China. Gujarat, ranking as the third-largest fruit producer in India after Maharashtra and Andhra Pradesh, serves as the focal point of the current study. This research aims to comprehend the growth patterns in the area, production, and productivity of major fruit crops across selected districts. To conduct this study, six specific fruit crops (mango, banana, sapota, citrus, guava, and papaya) were meticulously chosen based on their production, and five districts were selected for each crop based on their respective cultivation areas. The research utilized district-wise time series data encompassing the period from 2005-06 to 2020-21. Employing the compound annual growth rate and instability index, the study rigorously analyzed the growth patterns in the area, production, and productivity of major fruit crops. The study's findings revealed noteworthy growth in both the area and production of mango and banana in Gujarat during the study period, while productivity for these crops exhibited a non-significant growth rate. Conversely, for sapota, citrus, and guava crops, the growth rates in area, production, and productivity were positive and significant. In the case of papaya, the area and production demonstrated positive and significant growth rates, but the productivity growth rate was negative and significant.

Keywords: *Fruit Crops, Growth patterns, Compound Annual Growth Rate, Instability Index*

Horticultural Dynamics: A Comparative Analysis of Area, Production, and Instability in Key Fruits and Vegetables

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Abstract

Horticulture is emerging as a promising industry in India, with the ability to increase agricultural income, offer livelihood security, and create foreign cash through exports. Fruits and vegetables provide a considerable contribution, accounting for 90% of total horticultural production in India. The horticulture industry was responsible for 33% of total agricultural output in 2021-22. Fruits and vegetables are important in Gujarat, which has 7.4% of the Global Cropped Area (GCA). The current study examines the area and production patterns of five key fruits (mango, banana, pomegranate, guava, and papaya) and five vegetables (potato, onion, brinjal, okra, and tomato) in India and Gujarat. Secondary data collected from Gandhinagar, Gujarat's Directorate of Horticulture from 2005-06 to 2021-22. The investigation additionally examines at the influence of pricing on the cultivated area using trend analysis, and price volatility are examined using seasonality indicators. The extensive research intends to shed light on the changing trends and variables impacting horticulture output in both India and Gujarat by providing insights into the comparative dynamics, growth rates, and instability patterns within the cultivation of these essential fruits and vegetables. Most vegetables in Gujarat exhibited significant growth in area and production, except for brinjal in area and tomato and brinjal in production. Notably, banana, mango, and pomegranate showed substantial growth in area, while guava and pomegranate displayed growth in production. Instability was high for onion in both area and production in Gujarat, whereas other vegetables had low instability. In India, all vegetable crops demonstrated low instability. Papaya and pomegranate had medium instability in area and production in Gujarat, with pomegranate showing medium instability in India, while mango, banana, and guava had low instability.

Keywords: *Trend, Seasonality, Instability, Compound Annual Growth Rate, Volatility*

Optimizing Okra [*Abelmoschus esculentus* (L.) Moench]Genotypes Utilizing BLUP Methodology and Validating with MSTI Model

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Abstract

This investigation assessed the optimal genotype for a multi-environment experiment involving 35 okra genotypes across four different environments in 2019. Secondary data were gathered from the Department of Genetics and Plant Breeding at N. M. College of Agriculture, Navsari Agricultural University, Navsari. To be useful in a breeding or cultivar testing program, both stability and yield must be taken into account simultaneously to make genotype selection more exact and dependable. To identify stable genotype, the study employed the Modified Additive Main Effect and Multiplicative Interaction (Modified AMMI) as well as Best Linear Unbiased Prediction (BLUP) approaches to comprehend the causes of genotype-environment interaction (G x E) and that is validated through MTSI (Multi-Trait Stability Index). The study utilized BLUP-based simultaneous selection methods, including the Harmonic Mean of Genotypic Values (HMGV), Relative Performance of Genotypic Values (RPGV), and Harmonic Mean of the Relative Performance of Genotypic Values (HMRPGV). The findings indicated a significant genotype × environment interaction (GEI) in the pooled ANOVA. Additionally, the study demonstrated that both modified AMMI and BLUP-based methods were equally effective in selecting high-yielding genotypes with stable performance. Nevertheless, the BLUP approach was identified as the superior method for selecting genotypes with a substantial degree of stability. The BLUP-based approaches identified G12, G21, G9, G22, G10, and G13 as the most stable and high-yielding genotypes. Whereas results were accounted for MASV, genotype G2 was ideal as it has having higher mean yield as well as higher stability among all the genotypes and selection is rewarded for this genotype. Keeping the view of both high yield and stability, G10 is considered the ideal one. According to MTSI, genotypes G13, G2, G18, G8 and G11 are selected which are highly stable.

Keywords: *G x E, BLUP, MASV, stability, Modified AMMI, MET*

Prediction of Mango Prices in India: An Application of ARIMA using Python

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Abstract:

Mango is one of the most economically significant fruit crops in India. Mango prices directly affect the income of mango farmers. Fluctuations in prices can have a substantial impact on their livelihoods, influencing decisions related to cultivation practices, investment, and overall financial stability. Mango prices reflect market dynamics influenced by factors such as demand and supply. Monitoring and understanding these price trends are essential for stakeholders to navigate competitive markets effectively. Given the inherent volatility of agricultural markets, forecasting tools play a pivotal role in decision support. This study explores the application of Auto-Regressive Integrated Moving Average (ARIMA) models, known for their effectiveness in capturing time-series data for mango prices. For this study, time series data on monthly prices of mango fruit crops in India for the period of 2002 to 2023 were utilized. The best-performing ARIMA model was identified using monthly data for period of 2002 to 2022 using Python library and the ARIMA (1,1,1) model was determined to be the most suitable for predicting mango prices in India. Mean per cent deviation between predicted and actual data for the year of 2023 was 3.96 per cent. Additionally, 12-month forecast mango prices for the year of 2024 in India was generated using this identified model.

Keywords: *Time Series Analysis, Mango Price, Prediction, ARIMA, Python*

Optimizing Okra (Abelmoschus esculentus (L.) Moench) Genotypes through Parametric Models, TOPSIS approach, and MTSI Model for Prediction and Validation

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Abstract

This study was carried out by secondary data collected from the research done in the college farm, from Department of Genetics and Plant Breeding, N M College of Agriculture, Navsari Agricultural University, Navsari. This Large-Scale Varietal Trial (LSVT) of 35 genotype of okra having Line × Tester mating design over two seasons in four different environments viz., summer 2019, late summer 2019, kharif 2019 and late kharif 2019. The Multi Environmental Trial (MET) is one of the most essential elements in the crop development program since it demonstrates how a genotype performs in different environments. According to the results of this research, fruit yield showed highly significant GEI ($P<0.01$). The AMMI model achieved PC1 and PC2 of about 64.2 and 31.1 per cent of the total variations for the fruit yield of okra respectively. Based on AMMI model, G21 was the high yielding and the genotypes G11 and G2 were stable among all the genotypes. The same results were accounted by GGE biplot. TOPSIS technique was also employed in the research for the selection of stable genotype and it gave G21 as the most stable one since it has the lowest relative closeness value (0.013). the same result is validated through MTSI

Keywords: *Parametric, AMMI, GGE, TOPSIS, MTSI, Okra*

Forecasting Agricultural Prices Using ARIMA: A Case of Pineapple in the Major Market of Thiruvananthapuram, Kerala

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Abstract

The price of agricultural commodities fluctuates highly; they exhibit non-linearity, volatility, non-normality, and changing patterns. A distinctive feature of these price data is their reliance on past values to anticipate future outcomes. This emphasizes the importance of employing suitable methods for forecasting future results. The precision of these predictions plays a vital role in assisting farmers and policymakers in making well-informed decisions. Pineapple (Ananas comosus) is one of the important commercial fruit crops in Kerala, showing high price volatility. Proper price forecasting models are essential for farmers to decide on planting and marketing. This study focuses on the application of the Auto-Regressive Integrated Moving Average (ARIMA) models for forecasting pineapple prices in the major market of Thiruvananthapuram. Using a time series data of the monthly average price of pineapple from February 2012 to November 2023 different ARIMA models were fitted and the best fit were selected based on lowest value of RMSE and MAE. The ARIMA model's effectiveness in capturing time-dependent patterns makes it a valuable tool for enhancing price forecasting accuracy in the pineapple market. The timely and precise prediction of prices enables farmers to navigate between nearby markets to sell their produce and secure favourable prices.

Morpho-Physiological and Biochemical Profiling for Salinity Tolerance in Rice at Seedling stage under Hydroponic Conditions

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Abstract

Rice (*Oryza sativa* L.) is a key staple food crop consumed worldwide. High saline levels can significantly impact rice productivity, especially during the seedling stage. An effective strategy is to create a screening tool to discover genotypes with salt tolerance genes. Recognizing the urgency of this issue, there is an imperative need to develop climate-smart varieties or hybrids that can withstand and thrive in saline conditions. In this work, 15 rice genotypes were tested at the seedling stage to identify prospective salt-tolerant genotypes using a hydroponic system. To categorize tolerant and susceptible genotypes, several morphophysiological markers were applied, and biochemical determinants were examined to better understand the underlying tolerance process. Rice seedlings were treated with two salinity levels (EC-1.1 dSm–1 (control) and EC-14 dSm–1) for 20 days. The layout of the experiment was Completely Randomized Design (CRD) in a factorial fashion with three replications. Genotypes were raised using Yoshida solution to provide all essential nutrients to plants. In the experiment total of 17 characters have been studied viz., Salt evolution score, shoot length (cm), Root length (cm), Number of tillers per plant, Root volume (cm3), Seedling fresh weight (gm), Chlorophyll (SPAD), Total leaves, RWC %, Proline (µmoles/g of fresh wt), MSI %, Shoot NA+ mmol/g, Shoot K+ mmol/g, Root NA+ mmol/g, Root K+ mmol/g, Shoot NA+/K+ and Root NA+/K+, Salt stress resulted in significant decrease of growth and physiological traits in all genotypes; however, the lowest reduction was observed in some salt-tolerant genotypes namely IR55-179-3B-11-3, Pokkali, FL478, GR-19, Nona bokra, GNR5 and Dandi. Highest Na+/K+ ratio was found for O nivar, purna, devlikolam, NVSR2272, GR17, Lal kada gold, IR28 and Mahatma means this genotype is sensitive salt stress. To explore the potential biochemical basis of salt stress tolerance, six tolerant genotypes were further characterized along with a salt-sensitive genotype. The higher K+/Na+ ratios noted for all salt-tolerant landraces thus indicating that the K+/Na+ ratio serves as a reliable indicator of salt tolerance in rice. The higher increment of proline

content and MSI% were reported in salt-tolerant genotype as compared with salt-sensitive genotype. Therefore, these genotypes could be utilized as promising genotypes as a source of salt-tolerant parents in the hybridization program for the development of high-yielding salt-tolerant rice variety as well as in isolating salt-tolerant genes. At the end of conclusion, we found IR55-179-3B-11-3 and Pokkali where highly tolerant genotype under seedling stage salinity stress.

Study of genetic variability, correlation coefficient and path analysis in Mungbean [Vigna radiata (L.) Wilczek]

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Abstract

Mungbean [*Vigna radiata* (L.) Wilczek] is the third most important legume crop grown in India after chickpea and pigeon pea. Success of any crop improvement program depends upon the variability in the material. A large amount of variation is necessary in a breeding population to enable the breeder to carry out effective selection. All the genotypes displayed wide range of variation in their mean performance with respect to all the traits studied. The analysis of variance revealed significant differences ($P<0.05$) among mungbean genotypes for all the traits studied. The results showed that there is a presence of acceptable amount of variability among the genotypes. This gives an opportunity for mungbean breeders to improve these traits through selection. Thus, selection can be effective due to presence of adequate genetic variability among the individuals in the population. Yield is dependent variable and has more complex type of inheritance due to its polygenic nature. The knowledge of the extent of genetic association between yield and its contributing characters are useful in concentrating on traits that have positive correlation on seed yield per plant. The correlation coefficients between seed yield and its components and among the components were estimated at genotypic and phenotypic levels in the present investigation, highly significant association of seed yield per plant in desirable direction at both genotypic and phenotypic levels was observed for various traits viz., clusters per plant, pods per plant and 100-seed weight. Seed yield per plant also recorded significant and positive correlation at genotypic as well as phenotypic level with seeds per pod and pods per cluster. Path coefficient analysis revealed that the highest positive direct effect on seed yield per plant was recorded for 100-seed weight followed by seeds per pod and days to 50% flowering. Negative direct effect on seed yield per plant were unveiled by plant height, pods per cluster, pods per plant and protein contents.

Keywords: *Mungbean, variability, correlation, yield, path analysis*

Heterosis and Combining Ability Studies in Sesame [*Sesamum indicum* L.]

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Abstract

The research was undertaken to estimate heterosis and combining ability studies for seed yield and its component traits, which include days to 50% flowering, days to maturity, plant height (cm), effective branches per plant, capsules per plant, capsule length (cm), leaf area (cm2), seeds per capsule, 1000-seed weight (g), oil content (%), and seed yield per plant (g). The crosses were attempted using half diallel analysis involving eight parents and their 28 F1 hybrids with one standard check (GT-5) were evaluated in RBD with three replications at the Research Farm of Niger Research Station, Navsari Agricultural University, Vanarasi, Tal. Vansda, Dist. Navsari during Rabi-summer, 2020-21 for cross development, and an experimental material was evaluated during Rabi-summer, 2021-22. The analysis of variance for the experimental design found significant differences among genotypes for all the features, indicating that the material utilized had a high level of genetic variation. The differences between parents and hybrids were also discovered to be substantial for all the characters studied, implying that both parents and hybrids differed for all the characters. The mean sum of squares attributable to parents vs. hybrids and check vs. hybrids were both significant for all traits, demonstrating the presence of mean heterosis. Several crosses showed much greater parent heterosis and standard heterosis for seed yield per plant, among other characteristics. The estimations of better parent heterosis ranged from -35.17 percent

(AT-338 × JLS-2611) to 62.45% (AT-360 × ASRT-9). Standard heterosis had a range of variation from -43.15 percent (LT-15-28 × JLS-2611) to 30.06 percent (JLS-2420 × LT-15-28). Crosses with the highest heterobeltiosis and standard heterosis, such as JLS-2420 × LT-15-28 (30.1%), AT-338 × AT-360 (23.8%), AT-360 × LT-15-28 (23.2) and AT-360 × ASRT-9 (22.3%), show promise for seed yield and other desirable characteristics. These hybrids can be further evaluated to capitalize on the heterosis in future breeding programs and hybrid seed production technology. The mean total of squares owing to SCA was larger than the GCA for all characters, indicating that non-additive gene action predominated. All the studied characters had a σ2gca/σ2sca value less than unity, indicating a non-additive kind of gene effect. Combining ability investigation indicated both additive and non-additive gene effects. The estimates of general combining ability impacts indicated that parents AT-360 (1.247 **) and JLS-2420 (1.077 **) were good general combiners for seed yield per plant and associated traits. The estimates of SCA effects of crossings revealed that four of the 28 crosses had significant and favorable SCA effects on seed output per plant. The crosses JLS-2420 × LT-15-28 (3.88) had the largest SCA effects, followed by AT-360 × ASRT-9 (3.32), AT-338 × AT-360 (2.96), and AT-360 × LT-15-28 (2.95), all with considerable seed output per plant.

Keywords: *Sesame, Half diallel, better parent heterosis, standard heterosis, GCA, SCA, seed yield*

Optimization and Robustness of Energy Efficiency in Wheat Production using Data Envelopment Analysis

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Abstract

The purpose of this paper was to optimize energy utilization in wheat farming to mark existing practices more energy efficient. The study focused on estimating the energy use efficiency, input excess and output shortfall of concern DMUs and evaluating the robustness against data alteration using metric approach in data envelopment analysis. The collected data revealed that wheat farming utilized energy input of 16.98±0.75 GJ.ha−1. Out of total energy input, the share of renewable and non-renewable energy were 16% and 84%, respectively. There were statistically significant inefficiency observed in wheat production ($p<0.0001$) and result showed that out of total variation in energy output, 89% was due to technical inefficiency in energy utilization, whereas, only

11% was due to stochastic error. The results showed that on an average, an inefficient farmer could have saved significant amount of input energy in various form adopting optimized input energy without affecting their yield. The estimate of robustness measure (δ) were varied from 0 to 19.72 MJ.ha-1 and the efficient or inefficient position of a farmer was found to be robust against alteration in energy input and output within corresponding radius of stability.
Keywords: *Energy use efficiency, input energy, output energy, wheat production, slacks-based DEA, radius of stability.*

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