ABSTRACTS

National Seminar on Innovations in Agrophysics for Green Agriculture

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Organized by

The Indian Society of Agrophysics,
Division of Agricultural Physics, ICAR-IARI, New Delhi
and
ICAR- Indian Institute of Water Management,
Bhubaneswar

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on
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Efficacy of Nano-Urea Foliar Spray in Partial Substitution of Soil-Applied Conventional Prilled Urea in Rice

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Rice production depends heavily on nitrogen (N) fertilizer, yet N use efficiency remains low and fertilizer costs are a concern. We tested whether foliar nano-urea can replace part of soil-applied N in basmati rice (*Oryza sativa* L., cv. Pusa Basmati-1692) under field conditions at the Indian Agricultural Research Institute, New Delhi. Three N treatments were compared: the full recommended soil dose (120 kg N ha^{-1}; RDN), 75% of RDN plus two foliar sprays of 2% prilled urea, and 75% of RDN plus two foliar sprays of nano-urea (4 mL L^{-1}). Foliar sprays were applied at tillering and anthesis. We measured leaf pigments and gas exchange traits, water-use efficiency indicators, yield components, total plant N uptake, and post-harvest soil mineral N. Overall plant growth and several structural traits were broadly similar among treatments. Nano-urea increased leaf pigment concentrations at anthesis, but this did not improve photosynthetic rate or water-use efficiency relative to the full soil-N treatment; stomatal conductance and transpiration were comparable or slightly lower under foliar treatments. Yield components were generally similar across treatments, yet grain yield and total N uptake (grain + straw) were lower when nano-urea was used to substitute 25% of soil-applied N. After harvest, soils receiving nano-urea showed higher residual ammonium-N and lower nitrate-N, but this shift was not associated with higher N uptake or yield. These results indicate that, at the tested rate and timing, two foliar sprays of nano-urea did not compensate for a one-quarter reduction in soil-applied N in basmati rice. Further work should optimize spray timing and formulation and validate performance across seasons and locations before recommending nano-urea as a partial substitute for soil N.

Keywords: Nano-urea, Rice, N uptake, Nitrate-N

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Open-Source Multi-Satellite Synergy for Irrigation Scheduling in a Semi-Arid Irrigated Farm

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Agriculture uses about 70% of the world's freshwater withdrawals, so better irrigation scheduling is essential. Satellite remote sensing can support this by monitoring evapotranspiration (ET) and soil moisture over large areas in near real time. In this study, we tested an open-source, multi-satellite approach that combines Landsat 8/9 and Sentinel-2 data to support high-resolution irrigation scheduling. We estimated ET using six surface energy balance (SEB) models from Landsat optical-thermal observations and also using the Optical Trapezoidal Model-based Evapotranspiration method (OPTRAM-ET) derived from Sentinel-2 optical data. Among the SEB models, SEBAL performed best (r = 0.93; RMSE = 0.58 mm d^{-1}), while OPTRAM-ET also gave dependable ET estimates (r = 0.89; RMSE = 0.90 mm d^{-1}). Profile soil moisture was predicted using machine-learning models (Random Forest, Cubist, and Gradient Boosting Machine). We used Boruta feature selection to choose the most useful inputs from satellite indices, soil physical properties, and topographic variables. Boruta-assisted Random Forest and Gradient Boosting performed best (r = 0.83; RMSE = 2.9%), and predictors from Landsat were generally more informative than those from Sentinel-2. Spectral indices captured soil-moisture variability well down to 60 cm depth, while soil properties became more important at deeper layers. Finally, combining satellite-based ET and soil moisture within a field water-balance model improved estimation of irrigation water requirements and suggested possible water savings of up to 36%. Overall, the results show that open-access, multi-satellite data can support precision irrigation scheduling and more sustainable water management.

Keywords: Irrigation scheduling, Evapotranspiration, Surface energy balance, Soil moisture

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Emerging Pollutants in the Effluent of Wastewater Treatment Plants in Varanasi, India

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Micro-pollutants are reaching to water bodies as an emerging contaminant. Metabolites (forty eight compounds) were detected from different samples at five locations. Pharmaceuticals, pesticides, surfactants, drugs of abuse, metabolites, ceramide, derivatives, etc., were the major EPs. Methoxycinnamic acid, cyclandelate, and betaxolol in pharmaceuticals, 4-chlorophenoxyacetic acid, diazinon, and diuron in pesticides, and dihydrofarnesol in personal care products were identified as the most common compounds in the samples. This study considered retention time, molecular weight, chemical formula, and the total area covered in the mass spectrum, taking full advantage of the capacities of the HRMS instruments. These EPs have a direct and immediate impact on aquatic organisms and also have a subsidiary effect on humans and animals. Certain compounds have been associated with an elevated risk of hypertension and cardiovascular events, women's gynecological health, dermatological and ocular irritation, etc. Prioritization of EPs for designing, monitoring, and efficient management programs of water resources can be further done by ensuring the safety of the application of treated wastewater.

Keywords: Wastewater, Micro-pollutants, Metabolites

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Effect of Organic and Inorganic Amendments on Soil Properties Growth and Yield of Black Gram (*Vigna mungo* L.) in Red and Black Soils

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A pot experiment was conducted in glass house, UAS, Raichur, during the summer season of 2021 to study the effect of organic and inorganic amendments on soil properties, growth and yield of black gram in red and black soils. The experiment was laid out in completely randomized design (CRD) with sixteen treatments and three replications. The details of the treatments are control (without crop), control with crop, green manuring, FYM @ 5 t ha^{-1}, FYM @ 10 t ha^{-1}, FYM @ 25 t ha^{-1}, vermicompost @ 2.5 t ha^{-1}, Pusa hydrogel @ 0.05%, starch hydrogel @ 0.05%, humic acid (12%) drenching with 5 ml L^{-1}, straw mulch, seaweed extract @ 25 kg ha^{-1}, waste decomposer, gypsum @ 500 kg ha^{-1}, SSP @ 100 kg ha^{-1} and $CaCl_2.2H_2O$ @ 0.15%. Growth attributes (plant height, number of primary branches, number of leaves, leaf area, leaf area index and chlorophyll content per plant) were significantly higher with the application of vermicompost @ 2.5 t ha^{-1} which was closely followed by FYM @ 25 t ha^{-1} and seaweed extract @ 25 kg ha^{-1}, gypsum @ 500 kg ha^{-1}, SSP @ 100 kg ha^{-1} and $CaCl_2.2H_2O$ @ 0.15%. Yield attributes (number of pods, pod yield, 100 seed weight and stover yield per plant were significantly higher with the application of vermicompost @ 2.5 t ha^{-1} which was closely followed by FYM @ 25 t ha^{-1} and seaweed extract @ 25 kg ha^{-1}. There was higher improvement in soil physical, chemical, fertility and biological properties with application of FYM @ 25 t ha^{-1}.

Keywords: Black gram, Red and black soils, Soil properties

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Assessment of Geospatial Variability of Soil Secondary-Micro Nutrients in Soils of Odisha for Sustainable Crop Production

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A nutritional gradient or imbalance becomes evident throughout the farming areas due to uneven distribution of various nutrients. To address the issue of mismatch between fertilizer application rates and the actual crop nutrient demand, it is quite imperative to understand the location-specific variability in nutrient availability in order to administer nutrients based on soil fertility level. micro-secondary nutrients play a significant role in crop production which is hardly given importance. Micro-secondary nutrients management depends on its proper assessment due to narrow gap between deficiency and toxicity limits. To assess the soil fertility status with respect to micro-secondary nutrients for Odisha 12,000 no of surface soils (0-15 cm) were collected by using GPS from 314 blocks covering 30 districts of Odisha by AICRP on micro-secondary nutrients and pollutant elements in soils and plant. Samples were processed, analysed by standard procedure and assessed micro-sec nutrient data were subjected statistical analysis for range, mean, standard deviation, PSD and processed through arch GIS software for generation of fertility maps. Soil fertility maps were developed for secondary nutrients like Sulphur and micronutrients like Zn, Cu, Fe, Mn. From these maps it was found that Odisha soils were acidic, low in OC, mostly deficient in S, B, Zn and sufficient with respect to Fe, Mn, Cu. Fortyfour (44) percent of soils were deficient in plant available sulphur, 25.65% in DTPA extractable Zn. Highest deficiency for Boron was observed with PSD of 52.11 %. Deficiency followed the order B>S>Zn in decreasing order. Odisha soils were dominated by red soil and lateritic soils which are rich in Fe, Al, Mn oxides and hydroxides. Hence deficiency of Fe. Mn. Cu were limited to <1 % to 2 % only. Due to high annual rainfall and uneven surface terrain causes nutrient leaching leading to deficiency of anionic nutrients like S, B. It was also observed from delineation study that deficiency % increased over a period of 10 years. Hence nutrient management options must find the nutrients S,B,Zn to optimize the supply of all essential nutrients for sustainable crop production.

Keywords: Delineation, GIS, spatial variability

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Optimized Soil-Plant-Water Synergy: A Pathway to Healthy Soils and Sustainable Rice-Wheat Systems in Eastern Indo-Gangetic Plains

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Sustaining wheat productivity in the rice-wheat systems of the Indo-Gangetic Plains requires integrated management strategies to counter soil degradation, escalating water demand, and climate-induced stress. Responding to these challenges, a comprehensive two-year field experiment systematically quantified the interactive effect of rice establishment method (direct-seeded rice, DSR and puddled transplanted rice, PTR), tillage intensity (CT, RT and ZT) and irrigation scheduling [ETc-based (100, 75, and 50%) and IW/CPE: 1.0] on soil water balance, soil water flux, root water uptake, crop physiology, soil quality, water footprints, and system productivity in a rice-wheat-greengram rotation. The ETc-based irrigation is a novel, system-specific approach integrating soil, crop, and climate. The initial soil moisture advantage under PTR dissipated rapidly during wheat growth, whereas zero tillage consistently increased water storage by 7-12% and, when combined with DSR, reduced post-irrigation deep percolation losses by up to 42% compared with PTR-CT. These hydrological advantages promoted deeper and sustained root water uptake under DSR-ZT, enhancing compensatory extraction from subsoil layers during water stress and directing a greater proportion of actual evapotranspiration into productive transpiration. Physiologically, DSR-ZT maintained a favourable canopy microclimate, characterised by higher chlorophyll content (10-19%), moderated leaf angle dynamics, more negative canopy temperature depression (0.5-1.8°C), and consistently lower crop water stress index values. These responses collectively reduced moderate-to-severe stress days by up to 50% and extended the grain-filling safe period by 7-10 days. Improved soil physical, chemical, and biological properties under conservation management were reflected in an 8-13% higher soil quality index. At the system scale, DSR-ZT increased wheat yield by 7.7-9.0%, reduced the water footprint by 17.5%, and lowered greenhouse gas emissions by 16-19%, while maximising system productivity. Overall, integrating direct-seeded rice, zero tillage, and ETc-based irrigation offers a climate-smart, resource-efficient pathway for sustaining rice–wheat systems in the eastern Indo-Gangetic Plains.

Keywords: Rice-wheat systems, Indo-Gangetic plains, Soil-plant-water synergy

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Transforming Agricultural Systems for Climate Resilience: Synergistic Strategies and Innovative Pathways

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Climate change constitutes a profound threat to global agricultural systems, manifesting through elevated temperatures, erratic precipitation regimes, and intensified extreme weather events that diminish crop yields, impair livestock productivity, and provide constraints to resource availability. This review synthesizes knowledge on its effect while defining mitigation strategies such as encompassing conservation agriculture, agroforestry, and optimized nutrient/livestock management that potentially curtail greenhouse gas emissions and enhance carbon sequestration. However, widespread implementation is hindered by economic, technological, and institutional barriers, including high costs and insufficient policy support. Simultaneously, adaptation paradigms, including crop diversification, precision water husbandry, and climate-resilient cultivars, are imperative for maintaining agricultural productivity under changing climatic conditions. While integrated approaches like agroforestry offer co-benefits for mitigation and adaptation, they may also involve trade-offs, such as competition for land or water resources. Advancing resilient agroecosystems requires interdisciplinary research, robust data systems, and context-specific policies. Strengthening collaboration among stakeholders and aligning governance with international climate goals are essential to address knowledge and resource gaps, particularly in vulnerable regions, and to ensure long-term food security and livelihood sustainability. Future efforts must prioritize transformative adaptation that restructures agricultural systems toward greater resilience, rather than incremental adjustments. These demand exploitation of digital technologies for real-time monitoring and decision support, while investing in participatory breeding initiatives that expedite the dissemination of climate-adapted germplasm. Moreover, innovative financial mechanisms, such as hybrid financing models and resilience-linked insurance, are critical for mitigating risks and amplifying the adoption of sustainable methodologies. Ultimately, a nexus approach integrating water, energy, and food security policies will be fundamental in building systemic capacity to withstand compounding climatic and socio-economic stresses.

Keywords: Adaptation paradigms, Agroforestry synergies, Carbon sequestration, Climate resilience, Mitigation strategies

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Assessing the Ecosystem Services of Rice Farms in Coastal India

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Rice farming provides both tangible and non-tangible benefits to ecosystems which need to be maintained and enhanced. In this study, the ecosystem services (ES) of different districts of rice farms in the four agroclimatic zones of Odisha were valued by quantifying the economic value of the services under conventional rice cultivation, and the gap of ecosystem services value and farm income per unit area were assessed. The components of ES measured are: food (ES_1), by-products (ES_2), biological control of pests (ES_3), soil formation (ES_4), mineralization of plant nutrients (ES_5), carbon flow (ES_6), nitrogen fixation (ES_7), soil fertility (ES_8), hydrological flow (ES_9), and soil erosion (ES_{10}). Total ES values were estimated using the following equation:

$$ES_T = \Sigma ES_M + \Sigma ES_{NM} \quad (1)$$

Where ES_T = total ES value, ES_M = marketed (tangible) ES values and ES_{NM} = non-marketed (non-tangible) ES values.

The marketed value of ES comprised the sum of the economic value of products (grains) and by-products (rice straw) produced (Eq. 2), which are traded by farmers directly in the market. The remainder of the services are categorized as non-marketed ES values (Eq. 3) (McTaggart et al. 2003; Sandhu et al. 2008).

$$\Sigma ES_M = ES_1 + ES_2 \quad (2)$$

$$\Sigma ES_{NM} = \Sigma ES_{3\text{-}10} \quad (3)$$

The total marketed value for food and by products (raw materials) ranged from US$ 1699 $ha^{-1}\,y^{-1}$ (MCTL) to US$ 2736 $ha^{-1}\,y^{-1}$ (ESCP) with mean value of US$ 2187 $ha^{-1}\,y^{-1}$. The non-marketed ES were valued, which constitute ~61% of the total ES from rice field, in which gas regulation service through O_2 evolution was a major part (~55%). We propose implementing a range of strategies to narrow the economic disparity, such as the implementation of payments for ecosystem services specifically for rice cultivation aiming to promote the long-term sustainability of the ecosystem and agricultural progress.

Keywords: Ecosystem services, Rice farms, Coastal India

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Energy and Economic Evaluation of Rice Establishment Methods under Conservation Agriculture

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Conservation agriculture (CA) is a sustainable method of agriculture founded upon three basic principles: the reduction of soil disturbance achieved by zero tillage, the promotion of permanent soil cover by crop residues, and the conservation of biodiversity achieved by crop diversity. Today, conservation agriculture is gaining recognition for its potential to improve the structure of the soil and promote balance and sustainability of the environment. A comparative study was conducted in the ICAR-CRRI, Cuttack, having Inceptisol soils, to evaluate the differences in economic performance of conventional agriculture practices and conservation agriculture practices under rice-based cropping systems. Four rice establishment methods were assessed, (1) Conventional Direct-Seeded Rice (Conventional-DSR), (2) Zero-Tillage Direct-Seeded Rice (ZT-DSR), (3) Zero-Tillage Transplanted Rice (ZT-TPR), and (4) Conventional Tillage Transplanted Rice (CT-TPR). The current research was conducted to evaluate the energy dynamics and economic performance of different rice establishment methods. The primary objectives were to assess total energy input and output, energy use efficiency (EUE), net energy, and to analyse the costs of cultivation, yield, returns, and the benefit–cost ratio under different rice establishment methods. Energy inputs from all agronomic operations and materials inputs were converted into energy equivalents (MJ ha{ ^{1}), while energy output was estimated based on grain yield. Economic parameters were computed using the prevailing minimum support price (MSP) of rice. Zero-tillage practices significantly reduced energy input compared to conventional practices. Total energy input was lowest under ZT-DSR (6,871.11 MJ ha^{-1}), representing a reduction of about 35.62% compared to Conventional-DSR (10,673.07 MJ ha^{-1}). The energy use efficiency (EUE) varied among the treatments, with ZT-TPR recording the highest value (24.43), followed by ZT-DSR (22.85), CT-TPR (17.63), and CT-DSR (17.55). The net energy use efficiency of CT-DSR, ZT-TPR, and CT-TPR was 17.64%, 18.46%, and 14.16% higher, respectively, compared to ZT-DSR. Economically, ZT-DSR, CT-TPR, and ZT-TPR recorded 1.4%, 7.1%, and 13.6% higher benefit–cost ratios, respectively, over CT-DSR (1.40), with ZT-TPR showing the highest economic advantage (1.59). Although CT-TPR recorded a comparable yield, its higher cost of cultivation reduced overall profitability. The results confirm that conservation agriculture practices enhance energy and resource-use efficiency, reduce production costs, and improve profitability, offering a more sustainable and economically viable alternative to conventional rice systems.

Keywords: Energy, Economic evaluation, Conservation agriculture

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Mid-Season Assessment of Sensitive Soil Health Parameters Under Organic Nutrient Management Growing Aromatic Rice

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The aim of the second green revolution i.e. "more from less" focuses on higher productivity and income without degrading the environmental quality (soil, water, and biodiversity), emphasizes the needs of sustainable agricultural practices i.e. organic farming. Judging the potential of organic nutrient management (ONM) practices towards soil heath parameters, especially the mid-season changes, are not frequently reported with respect to physical (bulk density, moisture content), chemical (pH, electrical conductivity, nutrient availability,) and biological properties (microbial biomass carbon, enzymatic activities). To meet this research gap, a field experiment was conducted at the institute farm in the *kharif* season, 2025 where aromatic rice variety Poornabhog was grown. The seven distinct and sole organic nutrient treatments *viz*. T_1-(absolute) Control; T_2-Farm Yard Manure (FYM); T_3- Rice Straw Compost; T_4- FYM+ Rice Straw Compost (RSC); T_5- Bio-fertilizer +FYM; T_6- Bio-fertilizer +RSC; T_7- FYM+ green manure were established under randomized block design. Samples from active vegetative crop stage (60 DAT) were analysed and results revealed that ONM significantly enhances the oxidizable organic carbon content, mineralizable nitrogen over control, however pH, EC, moisture contents remained unchanged across treatments. The treatments, T_4 (FYM+ RSC) and T_7 (FYM+ green manure) showed the most significant increase in the activities of dehydrogenase, phosphatase, urease, and fluorescein di-acetate hydrolysis enzymes. The most significant rise in the dehydrogenase activity was noticed in T4 (147.4 μg TPF g^{-1} day^{-1}). Highest FDA and acid phosphatase activity were found in T7 (8.10 μg fluorescein g^{-1} h^{-1}; 5.32 μg pNp g^{-1} h^{-1}, respectively). Additionally, potentially mineralizable C (C_0), carbon rate constants (k_C), potentially mineralizable N (N_0), nitrogen rate constants (k_N) were also evaluated from same ONM treatments after 90-days incubation experiment to check the soil C-N dynamics. In a nutshell, ONM improves soil health through its direct and indirect benefits on mid-season soil bio-physico-chemical properties ensuring sustainability.

Keywords: Soil health parameters, Organic nutrient management, Aromatic rice

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Transportation and Transformation of Nitrogen in Rice Soil Influenced by Added Dose of Nitrogen Through Inorganic and Organic Source

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Rice is the stable food for the people of Odisha having the total production of 9 million tonne with the productivity of 3 t ha^{-1}. Rice productivity of Odisha can be improved by enhancing the nitrogen use efficiency either by increasing the doses of nitrogen with different sources of nitrogen. The present investigation was conducted in Agricultural research farm of Siksha O Anusandhan demanded to be university at Chhatabar during Kharif 2025 to generate some information through the transportation and transformation of nitrogen in rice field with graded dose of nitrogen through inorganic and organic sources having three replications and ten treatments i.e. T_1 (No Nitrogen), T_2 (50% of Nitrogen as per Soil Test Dose (STD)), T_3 (100% of Nitrogen as per STD), T_4 (100% of Nitrogen as per STD + crop residues @ 5 t/ha) and T_5 (100% of Nitrogen as per STD + F.Y.M @ 5 t/ha). The rice seedling of 27 days old (CV - Kaveri 21) transplanted in the research plot as per the treatment. The leachate sample was collected from the treatment plot with the help of soil sampler placed at two different depths i.e. at 10cm and 20cm. The leachate samples were analysed for NH_4^+-N and NO_3^--N and the breakthrough curves were drawn. Study revealed that in both the soil depth the highest concentration of NH_4^+-N was recorded with T_5 (100% of nitrogen as per STD + F.Y.M) followed by T_4 (100% of nitrogen as per STD with crop residues incorporation) and T_3 (100% of nitrogen as per STD). Similarly, in both the depths NO_3^--N content was also followed the similar trend. From this, it was conclude that NH_4^+-N and NO_3^--N Content was increased in solution phase due to application of FYM than that of crop residue application. Similarly, it was recorded that application of higher amount of inorganic fertilizer (T_3) increases the NH_4^+-N and NO_3^--N in the soil solution at two different depths.

Keywords: Nitrogen, Rice, Inorganic and organic Source

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Pixel-Level Wheat Yield Estimation by Modified Semi-Physical Modelling Approach

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With the advent of advanced algorithms and high-resolution remote sensing data, crop yield surveillance has become more efficient—reducing both labor and time costs while delivering greater accuracy than traditional Crop Cutting Experiments (CCEs). At the spatial level, such methods are essential for capturing yield variability at the farm scale, enabling data-driven decisions to enhance the productivity of small and marginal holdings. Even within a single district, yield heterogeneity arises from variations in weather, soil properties, sowing dates, management practices, and input use. These factors can be quantified more effectively through pixel-level crop modeling. This study explored the use of semi-physical approach for modelling wheat yield at pixel level in three districts of Uttar Pradesh. Using operational, moderate-resolution combined Sentinel-2A-2B constellation satellite imagery, and fusion of Sentinel-1 SAR data, a 20-m crop mask was generated by integrating Random Forest and Maximum Likelihood Classifier (MXL) algorithms. The MXL-based classification captured 95.6% of the officially reported wheat area, demonstrating strong agreement with APY statistics. Further, daily fractions of incident Photosynthetically Active Radiation (fIPAR) were derived using the PROSAIL model inversion for the crop season. Water stress (Ws) and temperature stress (Ts) impacts on photosynthesis were incorporated to refine wheat yield estimation at 20-m resolution using a semi-physical yield model for the districts of Unnao, Hardoi, and Kheri (Uttar Pradesh) during the 2024–25 growing season with RMSE 229 kg/ha, R^2 of 0.78 for the district of Unnao.

Keywords: Wheat, Yield, Estimation, Semi-physical modelling approach

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Comparative Assessment of Molecular Phosphorus and Nano Phosphorus on the Performance of Black Gram (*Vigna mungo* L.)

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Black gram (*Vigna mungo* L.), a vital pulse crop in India, accounts for about 10% of total pulse production. Phosphorus is essential for legume growth, but its use efficiency is low in acidic soils due to fixation. Nano-phosphorus offers a potential alternative by releasing phosphorus gradually, improving uptake efficiency. A field experiment was conducted during post kharif season of 2022 and 2023 using randomized block design with 8 treatments and 3 replications to evaluate black gram response to nano-phosphorus substitutions. Treatments included combinations of recommended dose of phosphorus (RDP) through single super phosphate (SSP) and foliar sprays (FS) of nano DAP or nano phosphorus at 15 days after sowing (DAS) and flowering. Results showed that 75% RDP through SSP + FS of nano DAP @ 5 ml L^{-1} significantly improved pod number (48.67), pod length (5.31 cm), seeds pod^{-1} (7.33), seed index (5.43 g) and yielded 20.13% and 55.44% higher seed yield than 100% SSP and control, respectively. This treatment also recorded the highest phosphorus uptake (13.38 kg ha^{-1}) and net return (¹ 37,507.46 ha^{-1}) with a return per rupee investment of 1.09. The study suggests that substituting up to 75% of molecular phosphorus with nano DAP enhances growth, yield and profitability of black gram in the terai region when supplemented with 20 kg N and 40 kg K ha^{-1}. This approach offers a sustainable fertilization strategy for post-kharif black gram cultivation.

Keywords: Black gram, Foliar spray, Nano particle, Phosphorus, Yield

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Performance Evaluation of IMD, ERA5, and CFSv2 Temperature Data against Station Observations Across India

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Reliable temperature datasets are essential for climate analysis, agrometeorological applications, and crop modeling; however, their performance varies across regions and seasons. This study evaluates the accuracy of widely used gridded and reanalysis temperature products such as IMD gridded data, ERA5 reanalysis, and CFSv2 forecasts, against real-time station observations across India. Seasonal biases in maximum temperature (Tmax), minimum temperature (Tmin), mean temperature (Tmean), and diurnal temperature range (DTR) were analyzed for monsoon, post-monsoon, winter, and summer seasons.

Results reveal distinct spatial and seasonal error patterns among the datasets. ERA5 shows comparatively lower bias and better spatial consistency across most regions and seasons, particularly for Tmean and Tmin. IMD gridded data exhibits systematic warm bias in Tmax and Tmean, especially during summer and post-monsoon seasons, with pronounced overestimation across central and northern India. CFSv2 demonstrates larger spatial variability and higher biases, notably during the summer season, where Tmax and DTR are substantially overestimated over large parts of the country. All datasets show reduced performance in representing DTR, indicating challenges in capturing sub-daily temperature variability.

Seasonal analysis highlights that biases are lowest during the monsoon season and highest during summer, emphasizing the influence of surface and atmosphere interactions and model physics. The findings underline the importance of region and season specific bias characterization before applying gridded and reanalysis temperature datasets in climate risk assessment, crop simulation modeling, and operational agrometeorological services. ERA5 emerges as the most reliable dataset among those evaluated, while bias correction is recommended for IMD and CFSv2 products for impact based applications.

Keywords: IMD, ERA5, and CFSv2 Temperature data

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Synergistic Effect of Salicylic Acid and Edible Coating Treatment on Postharvest Quality of Guava

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Guava fruits (cvs. Allahabad Safeda and Lalit) were treated with 5-Sulfosalicylic acid (2 mM) then coated with vegetable wax (1:4 v/v) and stored at 5°C or 10°C for 12 days. Post-cold storage, fruits were transferred to ambient conditions (20±2°C) for a 2 day shelf life simulation period. Observations were taken with an interval of 3+2 days up to 12+2 days. The results revealed that treated fruits showed significantly lower weight loss, chilling injury, pectin methyl esterase and malondialdehyde compared to control fruits. 5-Sulfosalicylic acid + Vegetable wax treatment also more effective in delay of fruit skin yellowing, respiration peak and ethylene evolution rate peak and also helped in retention of firmness, total phenolic content and total antioxidant capacity and higher ascorbic acid content during storage compared to control fruits, thus maintained the shelf life up to 12+2 days in 5°C stored fruits and 9+2 days for 10°C stored fruits.

Keywords: Salicylic acid, Edible coating treatment, Guava

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Fly Ash for Soil Health & Green Agriculture

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Fly ash (FA), a fine-grained byproduct of coal combustion in thermal power plants, is a significant industrial waste traditionally associated with environmental degradation. However, its physicochemical characteristics—as an amorphous ferro-aluminosilicate rich in essential nutrients—position it as a potential candidate for soil restoration and agricultural enhancement. This review explores the multifaceted role of fly ash as an "eco-friendly and economic" soil amendment, specifically examining its impact on soil health, microbial activity, and productivity of different cropping systems. Existing research reveals that FA significantly modifies soil physical properties, considerably increasing the water-holding capacity and porosity of sandy soils while reducing bulk density. Chemically, its alkaline nature serves as an effective liming agent, neutralizing soil acidity and enhancing the availability of macronutrients (P, K, Ca, Mg, S) and micronutrients (Zn, Fe, Cu, Mn, B). Biological evaluations indicate that low-to-moderate applications (typically ≤ 10% stimulate microbial biomass and enzymatic activities (e.g., urease, dehydrogenase). In contrast, high doses may inhibit these processes due to heavy metal toxicity and salinity. Specific crop responses highlight a "dose-dependent" benefit: maize yields generally peak at application rates of 10 t/ha, and root crops like carrots show significant increases in total protein and carbohydrates at 15% FA incorporation. Despite these benefits, risks of heavy metal accumulation (e.g Pb, Cd, As) remain primary concerns for long-term sustainability. Utilizing fly ash in agriculture promotes a circular economy by transforming industrial waste into a productive resource. However, the current agricultural utilization rate remains extremely low at 0.06%. To ensure safe large-scale adoption, there is a critical need for long-term field studies focused on residual effects and the distribution of heavy metals within the soil profile and crop tissues, particularly in intensive maize-vegetable rotations.

Keywords: Fly ash, Green agriculture, Heavy metal accumulation, Sustainable agriculture, Soil health

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Integrated Water and Nutrient Management via Drip Fertigation and Mulching for Sustainable Mango Production in Semi-Arid Regions

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Soil moisture and nutrients are critical for agricultural productivity, especially in arid and semiarid regions where they limit crop growth. This study examines the combined use of irrigation, mulching, and fertigation in southern Telangana, India, to enhance water and nutrient availability, assessing soil and leaf nutrient dynamics, fruit yield, and quality of mango. The present experiment conducted over two years with 16 treatments replicated thrice, it includes four irrigation (basin irrigation at 1.2 m^3/plant every 10 days, drip at 75%, 100%, 125% ETc daily) and four fertilization levels (500 g N&K via soil post-fruit set, 250, 375, 500 g of N&K via fertigation in three equal doses at 15-day intervals post-fruit set) and all the plants were mulched with silver colored polyethylene of 100 microns. The study found that 125% ETc with 375 g N&K fertigation and mulching significantly enhanced leaf nutrient and soil moisture availability (50%), water and nutrient use efficiency, fruit yield (60%), quality, and benefit-cost ratio, while saving 12.5% fertilizer compared to basin irrigation (1.2 m^3 water) with 500 g N&K soil application. Similarly, 75% ETc with 500 g N&K fertigation and mulching improved leaf, soil nutrients, moisture, water and nutrient use efficiency, fruit yield (50%) and with 30% water savings compared to basin irrigation and soil fertilization. Future studies should validate these findings across diverse soil and climates to confirm the broader applicability of 125% ETc drip irrigation with 375 g N&K fertigation $plant^{-1}$ and mulching as a fertilizer-saving approach, and 75% ETc drip irrigation with 500 g N&K fertigation $plant^{-1}$ and mulching as a water-saving approach for mango cultivation.

Keywords: Water use efficiency (WUE), Nitrogen and potassium use efficiency N&KUE, Soil moisture availability, ETc

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Biocolours as Eco-Friendly Food Colorants: Sources, Extraction, Stability, and Health Benefits from Plant Pigments

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Biocolourants, also known as natural colourants or "Biocolours," are pigments derived from renewable biological sources such as plants, algae, insects, fungi, and animals, predominantly plants. These colouring agents impart vibrant hues to food products while offering bioactive properties, including antioxidant, antimicrobial, and therapeutic benefits, making them preferable alternatives to synthetic food colourings associated with adverse health effects like ADHD, allergies, and behavioural issues. The review focuses on major biocolourants in vegetable crops, including carotenoids (e.g., β-carotene, lutein, lycopene) found in carrots, tomatoes, pumpkins, and leafy greens; anthocyanins responsible for red, purple, and blue shades in fruits and vegetables like purple carrots and eggplants; betalains providing red and yellow colours in beetroot and cactus fruits; chlorophyll imparting green hues; and anthoxanthins contributing creamy-white tones in cauliflower and onions. Key aspects discussed include sources, chemical structures, extraction methods (solvent-based, enzyme-assisted, supercritical fluid, pulsed electric field, etc.), stability factors (pH, temperature, light, oxygen), encapsulation and processing techniques (spray/freeze drying), and clinical applications such as photoprotection, antioxidant activity, vision enhancement, anti-cancer effects, and cardiovascular protection. Studies highlight variability in pigment content across cultivars, optimal extraction conditions for higher yields, and superior stability/retention under controlled storage. Overall, biocolourants represent eco-friendly, health-promoting substitutes for artificial dyes, aligning with consumer demand for sustainable, natural food additives that enhance both aesthetic appeal and nutritional value while minimising environmental and health risks.

Keywords: Biocolours, Eco-friendly food colorants, Plant pigments

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Exploring Genetic Diversity for Yield, Grain Quality, and Protein Content in Rice (*Oryza sativa* L.) Through Multivariate Analysis

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A diverse panel of 147 rice genotypes was evaluated for grain yield, grain protein content (GPC), and key grain quality traits with the objective of understanding the association of GPC with yield and quality parameters. Grain protein content showed a significant positive correlation with head rice recovery (HRR; r = 0.24), indicating the possibility of identifying genotypes combining high GPC with superior HRR. In contrast, GPC exhibited significant negative correlations with gel consistency (GC; r = -0.33) and kernel length (KL; r = -0.20), and a weak negative association with single plant yield (SPY; r = -0.12).

Head rice recovery was negatively associated with kernel breadth (KB; r = -0.39) and amylose content (AC; r = -0.22). Regression analysis revealed that GPC was largely influenced by GC, AC, HRR, and hulling percentage. Principal component analysis (PCA) indicated that four principal components accounted for approximately 72.0% of the total variability. Hierarchical cluster analysis grouped the 147 genotypes into ten distinct and divergent clusters.

The genetic diversity observed among the genotypes was mainly contributed by length-to-breadth ratio (L:B), kernel length, gel consistency, and kernel breadth. Clusters III to X exhibited a high degree of heterogeneity, suggesting their potential usefulness in generating desirable recombinants through hybridization. Overall, the results demonstrate that with systematic evaluation and well-planned breeding strategies, it is feasible to develop high-yielding, nutritionally enriched rice cultivars to address both food and nutritional security.

Keywords: Exploring genetic diversity, Grain quality, Rice, Multivariate analysis

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Genetic Parameters and Path Coefficient Analysis for Grain Protein Content, Quality Traits, and Yield in Rice (*Oryza sativa* L.) Germplasm Lines

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The present study was conducted to assess the extent of genetic variability among one hundred and forty-seven (147) rice germplasm lines for grain protein content, grain quality traits, and yield. Analysis of variance (ANOVA) revealed highly significant differences among the genotypes for all ten traits studied, confirming the presence of substantial genetic variability within the germplasm. The phenotypic coefficient of variation (PCV) values were only marginally higher than the corresponding genotypic coefficient of variation (GCV) values for most traits, indicating minimal environmental influence on trait expression and suggesting the potential for genetic improvement through direct selection. However, milling percentage and kernel breadth exhibited moderate PCV and GCV values, reflecting a relatively greater environmental effect on their expression.

Overall, high heritability estimates (>80.0%) coupled with high genetic advance as a percentage of the mean (>20.0%) were observed for all traits except milling percentage, which showed moderate heritability (47.8%) and low genetic advance (5.1%). The combination of high heritability and high genetic advance suggests the predominance of additive gene action, implying that selection would be effective for these traits. Path coefficient analysis indicated that protein yield per plant, length-to-breadth ratio, and head rice recovery exerted strong direct positive effects on grain protein content.

Keywords: Genetic parameters, Grain protein content, Yield, Rice, Germplasm lines

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Multistage Wheat Yield Prediction through Suitable Combination of Different Models Developed by Machine Learning and Deep Learning Techniques for Punjab

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Uncertainty associated with single-model wheat yield prediction was addressed by integrating five modelling approaches. NASA-POWER weather variables were used to predict yield at tillering, flowering, and grain-filling stages using Stepwise Multiple Linear Regression (SMLR), Artificial Neural Networks (ANN), Support Vector Regression (SVR), Random Forest (RF), and Deep Neural Networks (DNN). Stage-wise outputs were subsequently combined using six statistically distinct forecast-combination approaches: Bates–Granger (BG), Trimmed Eigenvector (E1G3), Inverse Rank (InW), Median (MED), Newbold–Granger (NG), and Simple Average (SA). Model skill was assessed using independent validation metrics (MAPEv, RMSEv, nRMSEv, MAEv, and PDEV), capturing accuracy, dispersion, and bias. Across all phenological stages, Simple Average (SA) exhibited the highest robustness and phenological stability, consistently achieving low validation errors with limited bias. While no single method dominated every growth stage, NG performed relatively better during the highly variable tillering stage, whereas E1G3 showed strong structural sensitivity, with useful skill confined to isolated late-season. MED and InW offered moderate robustness but lacked consistent dominance, reinforcing the resilience of simple averaging under NASA-POWER forcing. District-level analysis showed that SA was the only method delivering stable performance. Other methods improved skill only under specific stage–district combinations, while MED and E1G3 frequently exhibited inflated errors. In districts with shorter and uneven data records, no combination model showed uniform superiority; performance became strongly dependent on phenological stage and data length. Overall, forecast combination reduced prediction error with maximum during flowering and grain filling. The proposed multistage integration framework therefore provides a robust and operationally reliable basis for district-level wheat yield prediction under variable climatic conditions.

Keywords: Wheat, Machine learning and deep learning techniques, Punjab

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Spatial Monitoring and Mapping of Soil Hydraulic Properties through Visible-Thermal-Microwave Remote Sensing along the Indian West Coast

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Soil moisture at field capacity (FC) and permanent wilting point (PWP), along with soil organic carbon (SOC), was estimated for coastal districts of Karnataka. FC, PWP, and SOC ranged from 2.15–53.77%, 0.9–32.57%, and 0.09–1.97%, with mean values of 20.67%, 12.68%, and 0.88%, respectively. Spectral responses showed adequate variation for prediction of soil properties. Although some machine learning models performed well during calibration using raw spectra ($R^2 > 0.75$, RPIQ > 2.5), validation performance was poor (RPIQ < 2.0). Model performance improved significantly when using partial least square regression (PLSR) scores instead of raw spectra. Cubist performed best for FC, while PLSR was optimal for PWP and SOC. For spatial prediction, 44 covariates derived from Landsat-8, Sentinel-1, and Shuttle Radar Topography Mission-Digital Elevation Model (SRTM-DEM) were generated. Boruta feature selection identified key predictors for model development. Based on overall ranking, RF performed best for FC and PWP mapping, while PLSR ranked highest for SOC but failed to capture its spatial variability; therefore, extreme gradient boosting (XGB) was used for SOC mapping. Radar backscatter in vertical-vertical polarisation (Sigma0_VV) was the most important variable for FC, land surface temperature (LST) for PWP, and DEM-derived variables for SOC.

Keywords: Field capacity, Permanent wilting point, Landsat-8, Sentinel-1, and SRTM-DEM

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Hydrogel/Superabsorbent Polymer for Water and Nutrient Management in Horticultural Crops

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Water scarcity poses a major challenge to global agriculture, particularly in arid and semi-arid regions where irrigation inefficiencies, nutrient leaching, and adverse soil properties limit crop productivity and quality. Superabsorbent polymers (SAPs), commonly known as hydrogels (e.g., Stockosorb, Raindrop, Agrosorb), are cross-linked hydrophilic polymers capable of absorbing and retaining large volumes of water and nutrients, releasing them gradually to plant roots as soil moisture depletes. This review synthesizes research findings on the role of hydrogels as soil conditioners in horticultural crops, including citrus, banana, vegetables, turf, and nursery production. Hydrogels enhance soil physical properties by increasing water-holding capacity, porosity, infiltration rates, and aeration while reducing compaction, evaporation, runoff, and nutrient leaching. They extend irrigation intervals, improve water use efficiency (WUE), mitigate drought stress, and support plant growth under reduced water regimes. Application methods vary from incorporation into growing media, seed coatings, root dipping, banding, broadcasting, to injection in orchards and turf. Reported benefits include improved seed germination, root development, vegetative growth, earlier flowering, higher yields, better fruit quality (e.g., size, sugar content, ascorbic acid), and enhanced nutrient uptake. In field trials, hydrogels have enabled 20-50% reductions in irrigation water without compromising yield, while increasing crop tolerance to salinity and drought cycles. Despite limited long-term data on polymer degradation, hydrogels represent a promising, sustainable tool for optimizing water and nutrient management in horticulture, particularly on sandy or well-drained soils prone to rapid moisture loss. Further research is needed to refine application rates, long-term efficacy, and cost-effectiveness across diverse crops and environments.

Keywords: Hydrogel, Superabsorbent polymer, Stockosorb, Water use efficiency, Soil conditioner, Drought mitigation

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An Evaluation of Quantity-Intensity Relationship of Potassium on Some Low Land Rice Growing Soils

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Potassium (K) supplying capacity of some low land rice growing soils was investigated by employing the quantity-intensity (Q/I) approach. The values of potential buffering capacity (PBC^K), labile (K_L), Specific K (K_O), specific K sites (K_X), equilibrium activity ratio (AR^K) and free energy change (-ÄG) were estimated from the quantity-intensity curve. Non-specific K values changes with clay mineralogy and organic matter content. Higher cation exchange capacity and organic carbon favours labile K pool. Low equilibrium activity ratio indicates that bulk of K was preferentially held at edge position of the clay crystals. Higher potential buffering capacity (PBC^K) indicates excellent K-status. PBC^K is directly proportional to the free energy change of potassium. The changes of Q/I parameters is associated with the contents of clay, organic matter and clay mineralogy of the soil. Higher exchangeable cations in soil matrix favours labile K, specific K and specific K sites.

Keywords: Quantity-intensity relationship, Labile K, Specific K, Specific K sites, Free energy change, Equilibrium activity ratio

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Effect of Water Management on Resource Conservation Technologies on Water and Nitrogen Productivity in Maize-Sunflower Cropping System

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A field experiment was carried out in a two-year-old ongoing field experiment on maize-sunflower cropping system during the year 2023- 24 to evaluate water productivity and partial factor productivity of nitrogen (PFPN) of maize-sunflower sequence under different water management practices in resource conservation technologies in a sandy clay loam soil of ICAR – Indian Institute of Water Management research farm, Bhubaneswar. The treatments comprised of different combinations of resource conservation technologies and irrigation methods viz., (T1) Conventional-till flatbed flood irrigation; (T2) Permanent broad-bed and furrow irrigation; (T3) Permanent broad-bed and furrow irrigation with residue; (T4) Permanent narrow-bed and furrow irrigation ; (T5) Permanent narrow-bed and furrow irrigation with residue ; (T6) Zero-till drip irrigation; (T7) Zero-till drip irrigation with residue; (T8) Zero-till flatbed flood irrigation with residue; (T9) Zero-till sub-surface drip irrigation and (T10): Zero-till sub-surface drip irrigation with residue. It was observed that resource conservation technologies improved grain yield, water productivity and PFPN of maize and sunflower than conventional tillage under flood irrigation. Drip irrigation and subsurface drip irrigation resulted in higher grain yield, water productivity and PFPN of maize and sunflower than flood irrigation. There was no significant difference between drip and subsurface drip irrigation with respect of yield, water productivity and PFPN for maize but for sunflower, subsurface drip irrigation resulted in significantly higher yield, water productivity and PFPN than drip irrigation. Residue retention resulted in higher water productivity and PFPN for maize and sunflower than residue removal. Zero tillage with residue retention under subsurface drip irrigation registered significantly higher water productivity and PFPN than conventionally tillage with flood irrigation in maize-sunflower cropping system. Thus, the present study recommends resource conservation technologies with drip or subsurface drip irrigation for improving yield, water productivity and partial factor productivity of nitrogen in maize-sunflower cropping system.

Keywords: Resource conservation technology, Water productivity, Partial factor productivity of nitrogen

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Effect of Zinc Oxide and Ferric Oxide Nanoparticles on Wheat

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Micronutrient deficiencies are a major limitation on wheat productivity and grain nutritional quality in many agricultural soils. Recent advances in nanotechnology offer a promising approach to improve nutrient use efficiency through the targeted delivery of essential micronutrients. In this context, a field experiment was conducted to evaluate the effects of zinc oxide (ZnO) and ferric oxide (Fe_2O_3) nanoparticles on the growth, yield, and physiological performance of two wheat (*Triticum aestivum* L.) cultivars, HD 3226 and HD 3298.

The experiment was conducted using randomized block design with seven treatments involving foliar application of ZnO and Fe_2O_3 nanoparticles at the jointing and grain-filling stages. Treatments included foliar sprays of ZnO nanoparticles, Fe_2O_3 nanoparticles, a combined application of ZnO + Fe_2O_3 nanoparticles, zinc sulfate ($ZnSO_4$), ferrous sulfate ($FeSO_4$), a combined $ZnSO_4$ + $FeSO_4$ treatment, and an untreated control. ZnO and Fe_2O_3 nanoparticles were applied at rates of 0.962 kg ha^{-1} (0.2% w/v) and 0.6 kg ha^{-1} (0.138% w/v), respectively. Equivalent amounts of zinc and iron were supplied through $ZnSO_4$ and $FeSO_4$ to enable direct comparison between nanoparticle-based and conventional micronutrient sources.

The results showed that foliar application of ZnO and Fe_2O_3 nanoparticles significantly ($p < 0.05$) improved wheat growth and physiological parameters, particularly SPAD values, in both cultivars compared with $ZnSO_4$, $FeSO_4$, or their combined application. Yield-related traits, including spike length, number of grains per spike, biomass production (m^{-2}), and grain yield (m^{-2}), were also significantly ($p < 0.05$) enhanced under nanoparticle treatments. Overall, nanoparticle-based foliar nutrition increased grain yield by 22.6–25.8% compared with the control. These findings indicate that ZnO and Fe_2O_3 nanoparticles are more effective than conventional micronutrient fertilizers in improving wheat performance under field conditions.

Keywords: Zinc oxide, Ferric oxide, Nanoparticles, Wheat

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Optimizing Tillage and Residue Management in a Rice–Potato–Pumpkin Sequence for Yield and Soil Resilience in Eastern India

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This two year field study evaluated a rice–potato–pumpkin cropping system under conservation agriculture such as conventional tillage (CT), reduced tillage (RT), and zero/ no tillage (ZT) with five nutrient–residue regimes (NR1– NR5) during the years period 2019-21 at Haringhata, West Bengal, India. Results showed that CT + NR4 (100% RDF + 50% residue retention) produced the highest system performance: rice grain yield 4.66 t ha^{-1}, potato tuber yield 29.78 t ha^{-1}, and pumpkin yield >25 t ha^{-1}. Growth dynamics showed clear tillage × nutrient interactions: pooled (crop growth rate) CGR (g m^{-2} day^{-1}) for CT was 22.13, 20.20, 12.97 across successive intervals, compared with RT (21.03, 18.97, 12.30) and ZT (20.53, 19.40, 12.40). LAI (leaf area index) and dry matter accumulation peaked under CT and NR4 (e.g., LAI pooled at 60 DAT ≈ 4.2 for CT; NR4 pooled LAI ≈ 4.24). Baseline soil status showed SOC 0.35%, available N 232.5 kg ha^{-1}, and microbial counts (bacteria ≈ 40×10v CFU g^{-1}). Conservation treatments (ZT/RT with residue retention) improved biological indicators and nitrogen recycling, while residue retention enhanced dry matter and LAI. Results indicate that combining optimized nutrient management (NR4) with appropriate tillage can raise yields and improve soil resilience, supporting CA as a viable pathway for sustainable intensification in the Lower Gangetic Plains.

Keywords: Conservation agriculture, Tillage systems, Soil health, Crop productivity, Rice–potato–pumpkin

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Soil Potassium Dynamics Under Resource Conservation Practices in Long-Term Rice-Based Cropping System

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Resource conservation technologies (RCTs) have evolved to address present agricultural challenges like soil degradation, disturbed nutrient cycling and SOM depletion, especially for small-scale farmers in tropical and sub-tropical regions. RCTs offer multiple benefits, *viz*. labour and energy savings, leads to less C footprint and ensure optimized resource utilization (Deng et al. 2024; Jat et al. 2021). Among three major nutrients, soil potassium is even very less studied when resource conservation practices are concerned. However, it is equally important if the soil nutrient budgeting is involved to meet the benefit of RCTs. We observed that a significant variation in different K fractions (available, water soluble, exchangeable, non-exchangeable) and total K under seven different set of treatments both in direct seeded (DSR) and transplanted rice (TPR) system after ten years of field experimentation (rice-green gram cropping system). Under both systems, green manuring + 75% RDF-N significantly improve the labile and exchangeable K content in the soil (130.2, 122.5 mg kg^{-1} for K_L; 111.1, 102 mg kg^{-1} for K_{ex}, respectively), which had direct influence in K-availability. However, soil applied with 100% RDF-N under DSR and green manuring + 75% RDF-N under TPR showed significantly higher water-soluble content (20.2 and 20.6 mg kg^{-1} respectively) over other treatments. The maximum contributing fraction towards total-K content was found to be exchangeable K and minimum was water soluble. Zero-tillage treatments (both DSR and TPR conditions) had significant influence towards labile K (K_L) and non-exchangeable K (K_{nx}), while mean K_L is TPR> DSR conditions. Further from Q/I study, it was revealed that, under DSR, almost all treatments are deficient of K ($\ddot{A}G_0$), however, the mean values under TPR condition are lower and indicates less overall deficiency of K. Under TPR, Green Manuring +75% RDF-N had higher K_s and determines labile K. This is inferred that RCT practices showed its significant impact towards K dynamics (both K fractions and Q/I parameters) under long-term experimentation.

Keywords: Soil potassium dynamics, Resource conservation practices, Rice

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Optimising Drone Spraying Parameters for Enhanced Uniformity and Efficiency

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This study focuses on optimising drone-based spraying parameters to enhance spray uniformity, droplet deposition, and application efficiency in precision agriculture. Several interacting factors, including nozzle type and angle, operating pressure, flight speed, spraying height, and effective swath width, influence drone spraying performance. Identifying an optimal combination of these parameters is essential to minimise variability and ensure uniform droplet distribution across the crop canopy. Field experiments were conducted using two multi-nozzle configurations: Configuration A (EXT: 110°–110°–110°–110°) and Configuration B (MODI: 80°–110°–110°–80°). Field experiments were conducted using a multi-rotor agricultural drone equipped with two distinct multi-nozzle configurations: Configuration A (EXT: 110°–110°–110°–110°) and Configuration B (MODI: 80°–110°–110°–80°). Spraying trials were performed at operating pressures of 1, 2, 3, and 3.5 bar, flight speeds of 2 m s{ 1 and 3 m s{ 1, and spraying heights of 1 m, 2 m, and 3 m above the crop canopy. Swath width and spray overlap were evaluated under predefined flight routes to determine effective spray coverage. Droplet deposition characteristics were quantified using water-sensitive papers placed within the crop canopy. Droplet coverage percentage and droplet size distribution were derived from the collected samples. Spray uniformity was assessed using the coefficient of variation (CV) for droplet coverage and the Relative Span Factor (RSF), calculated as $(DV_{90} - DV_{10})/DV_{50}$, where lower values indicate greater uniformity. Results demonstrated that both nozzle configuration and operational parameters had a significant influence on swath width, droplet coverage, and spray uniformity. Configuration B consistently produced lower CV and RSF values compared to Configuration A, particularly at higher spraying heights. Among the tested combinations, the optimal operating condition was identified as Configuration B operated at 3 bar pressure, 2 m s^{-1} flight speed, and a spraying height of 3 m, which resulted in minimal variability and more uniform droplet deposition. These findings provide practical guidelines for improving the efficiency and precision of drone-based pesticide and nutrient applications.

Keywords: Drone spraying, Nozzle configuration, Spray uniformity, Droplet deposition, Precision agriculture

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Automatic Water Level Sensor based Irrigation in Paddy

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A field experiment was conducted at IARI research farm with aim to integrate wireless water level sensor to check gate and evaluate the system for irrigation scheduling in transplanted rice. The experimental plot size was 18x8 m^2, and four irrigation treatments were established based on different threshold ponding water level I_1 (5 cm), I_2 (3 cm), I_3 (2 cm) and I_4 (conventional farmers practice). Wireless water-level sensors were installed and connected to the check gate at main channel though LoRa and GSM communication protocol. Irrigation was trigged when the water level was depleted by ≥50% of the respective threshold level. The total depth of irrigation water applied varied significantly among the treatments. The cumulative irrigation depths were 23.21, 18.54, 12.25 and 29,75 cm under I_1, I_2, I_3 and I_4 respectively. The conventional irrigation practice resulted in the highest water application, where as the sensor-based irrigation treatments substantially reduced irrigation water use. Overall, the adoption of real time water level sensor based irrigation scheduling resulted in nearly 30% water saving compared to conventional irrigation. This reduction in water use can be attributed to timely and need based irrigation controlled through automated sensing and communication technologies, which minimized over irrigation and unnecessary water losses.

Keywords: Water level, Sensor, Irrigation, Paddy

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Identifying Soil Drivers of Rice Productivity under Fly Ash and Organic Amendments Using Explainable Machine Learning

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Declining soil quality and nutrient imbalances constrain rice productivity in tropical acidic soils. The agricultural reuse of fly ash (FA), an industrial by-product, offers potential as a soil amendment when combined with organic inputs, yet mechanistic understanding of its effects on soil–yield relationships remain limited. Traditional statistical methods often fail to decode non-linear soil-yield relationships, necessitating advanced machine learning (ML) approaches. A field experiment evaluated the integrated effect of FA (10–40 t ha^{-1}), FYM (5 t ha^{-1}), and NPK effects on soil physio-chemical and biological properties and identified key soil predictors driving rice productivity using explainable machine learning. The FA40+FYM+NPK treatment achieved the highest grain yield (54.0 q ha^{-1}), outperforming NPK alone by 38.5%. This treatment improved soil porosity (45.5%), water-holding capacity (37.8%), available nitrogen (212.9 kg ha^{-1}), available phosphorus (19.6 kg ha^{-1}), and microbial enzyme activities, including urease (22.9 μg NH_4^+ -N g^{-1} hr^{-1}) and β-glucosidase (15.1 μg pNP g^{-1} hr^{-1}). Machine learning interpretation revealed β-glucosidase, organic carbon, urease, available phosphorus, and clay content as dominant predictors of yield variation. Conditional partial dependence plots revealed synergistic interactions between β-glucosidase and organic carbon, and between urease and available phosphorus, indicating that carbon turnover and nutrient mineralization jointly regulated yield response. These findings demonstrate that the combination of FA (20–40 t ha^{-11}) with FYM and NPK can improve soil functionality and sustain rice productivity. Explainable modelling provides mechanistic insight for advancing soil health assessment and fertilizer strategies in acidic agroecosystems.

Keywords: Conditional random forests, FYM, Organic carbon, β-glucosidase, Soil health, Acidic soils

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Assessment of Aquifer Vulnerability to Seawater Intrusion in Coastal Puri District of Eastern India

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With climate change and population expansion, the management of coastal aquifer systems is becoming increasingly crucial. At present, several coastal cities in India are facing the environmental problem of seawater intrusion. Effective planning and management is required for mitigation of such problems in coastal aquifers. The present study was conducted to identify the spatial distribution of seawater intrusion in the coastal aquifers of Puri District in the state of Odisha. In the present study, the vulnerability of aquifers to saltwater intrusion was assessed by GALDIT, an index-based method. To quantify the spatial extent of susceptibility of coastal intrusion, six hydro-geological characteristics were considered in the model such as G: Aquifer type, A: Conductivity of aquifer, L: Level of groundwater above MSL, D: Perpendicular distance from the shoreline, I: Impact of marine intrusion, and T: Saturated thickness of aquifer. Different weights and ratings were assigned to these layers according to the model and overlay analysis of the layers was done for mapping the seawater intrusion vulnerability map. For the pre-monsoon, susceptibility zones are categorized as low, moderate, and high, with percentages of 75.12 %, 22.84 %, and 2.034 %, respectively. Similarly, for the post-monsoon season, 78.07 %, 21.08 %, and 0.84%, area are categorized under low, moderate and high susceptible zones. The Gop block was found to be the most susceptible area in the region. The level of groundwater above MSL and perpendicular distance from the shoreline were found as most sensitive parameters and thickness of aquifer was the least sensitive parameter for groundwater contamination in the study area.

Keywords: Seawater intrusion, Coastal aquifers, GALDIT

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Quantitative Assessment of CO_2, H_2O and Energy Fluxes Over the Jute Agroecosystem using Eddy Covariance Technique

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In a maiden attempt, the eddy covariance method was used to continuously measure the CO_2, water vapor and energy fluxes from the jute agroecosystem in the lower Indo-Gangetic plain region. The cumulative Net Ecosystem CO_2 Exchanges (NEE) over the jute season varied from 150 to 268 g C m^{-2} indicating the ecosystem to be significant net CO_2 sink. However, the ecosystem was found to be net CO_2 source during night time with NEE values of 5-10 μmol m^{-2} s^{-1}. The diurnal variations of NEE were found to be strongly influenced by the growth stages of jute crop. The diurnal variation of NEE was found to be strongly correlated with photosynthetic photon flux density (PPFD) over the different growth stages of jute crop (R2>0.9). The relationship was used to retrieve ecosystem level photosynthetic efficiency parameters following Michaelis-Menten equation. In the jute ecosystem energy balance computation, the LE values were maximum in maturity stage of jute. During jute season, daytime average Rn, G, H, and LE were 323.4 (±156.3), 9.0 (±8.4), 12.1 (±8.8), and 180.4 (±71.6) Wm^{-2}, respectively. The Rn was majorly partitioned into LE (55.8%), followed by H (3.7%) and G (2.8%). The degrees of energy balance closure varied from 58% to 68%. Very strong positive correlations (R2~0.94-0.98) between available and turbulent energy were observed the different growth stages of jute. The results of the present study would significantly contribute to address the carbon, moisture and energy fluxes from the Indian ago-ecosystem, which is otherwise is very sparse. These high frequency data will be useful for evaluating carbon farming, validating and improving land surface and crop models, and providing ground-truth measurements for satellite-based estimations of regional evapotranspiration (ET) and gross primary productivity (GPP).

Keywords: CO_2, H_2O, Jute agroecosystem

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Challenges and Opportunities for Precision Irrigation in Hilly Terrain

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Precision irrigation offers significant potential for improving water use efficiency and crop productivity in hilly terrains, where traditional irrigation methods often fall short due to complex topography, uneven soil distribution, and accessibility issues. The present approaches focus on the integrated application of soil moisture sensors, Internet of Things (IoT) technologies, and solar power as critical components in overcoming these challenges. Soil moisture sensors provide real-time, localized data necessary for site-specific irrigation, while IoT platforms enable remote monitoring and automated decision-making. However, their effectiveness in hilly regions is limited by difficulties in sensor placement, soil heterogeneity, unreliable connectivity, and high operational costs. In this context, solar-powered systems emerge as a sustainable solution to power sensor networks and communication modules in off-grid or energy-scarce areas. The combination of IoT, soil moisture sensing, and solar energy has the potential to transform irrigation practices in hilly regions, making them more precise, autonomous, and resource-efficient. The technological, infrastructural, and socio-economic challenges associated with deploying these systems for their scalable and sustainable implementation in hilly agricultural landscapes is emerging opportunities to improve agricultural productivity and livelihood of the farmers community.

Keywords: Agriculture, Irrigation, Internet of things, Sustainability, Water

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Colour Thresholding versus Deep Learning Approaches for Image-Based Monitoring of Potato Canopies under Diverse Field Conditions

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Precise, quantitative assessment of crop growth and stress through non-destructive techniques is a common concern in agro-physics, as canopy structural dynamics govern radiation interception, energy balance, and biomass accumulation. Image-based estimation of canopy cover provides a practical surrogate for key biophysical attributes; however, its robustness across crop genotypes, illumination conditions, stress environments, and phenological stages remains insufficiently examined. This study compares the performance of a conventional threshold-based method (Canopeo mobile application) with a deep learning-based semantic segmentation model (PCCSegNet) for monitoring canopy development and stress responses in potato (*Solanum tuberosum* L.).

Field observations were conducted at Jalandhar, Punjab (31°16′34″ N, 75°32′51″ E; ~230 m AMSL) over three *rabi* seasons (2022-23 to 2024-25), encompassing contrasting water management practices (weather-based drip irrigation scheduling and thumb-rule based furrow irrigation) and variable nitrogen regimes. Three genetically distinct potato varieties, namely, *Kufri Jyoti, Kufri Himalini*, and *Kufri Khyati*, were considered to represent differences in canopy architecture and growth behaviour. Particular attention was given to assessing model sensitivity in estimating green canopy cover under edge conditions, primarily arising from sun-angle variability, which influences reflectance anisotropy, shadow fraction, and canopy-background contrast. Model performance was further examined under abiotic stress environments, including nitrogen and water stress, which induce biophysically driven changes in leaf area expansion, canopy continuity, and spatial as well as spectral heterogeneity. Evaluations spanned multiple crop growth stages to capture temporal variations in canopy structure from early establishment to advanced growth phases. The initial findings highlight the robustness and advantages of a deep learning-based approach for generating reliable canopy information under diverse environmental and complex biophysical conditions and support its application in data-driven precision agriculture, stress diagnostics, and real-time monitoring systems for potato crops.

Keywords: Canopy biophysics, Potato, Visual imaging, Canopeo, PCCSegNet, Reflectance anisotropy, Abiotic stress, Digital agriculture

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Aphid Population Dynamics in Mustard Cultivars and Temperature Relationships

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Aphid (*Lypaphis erisimi* Kalt.) is the number one pest of Indian mustard cultivars. It causes serious damage to the crop during the flowering to siliqua filling stage, resulting in a yield loss of up to 90%. Aphid population is also sensitive to temperature. To study the population dynamics of mustard aphid, a field experiment was conducted during the *rabi* crop season of 2024-25 with two sowing dates- 31st October (i.e. normal sowing and 28th November (i.e., late sowing), and three cultivars - Pusa Vijay, Pusa Mustard 31 and Pusa Mustard 33. Aphids appeared first in the second week of December, reached the peak population in the 3rd /4th week of February, and then started declining. Significantly higher aphid population was recorded in the late sown crop than that in the normal sown crop. The flowering stage in the late-sown crop occurred during January-February in comparison to that of the timely sown crop, which was December-January. The daily mean temperature of January-February was 2 °C- 3 °C higher than that of December-January. At higher temperatures, the aphid multiplied at a faster rate, probably. The cultivar, Pusa Vijay, recorded a lower aphid population than the other two recently developed cultivars, Pusa Mustard 31 and Pusa Mustard 33. The regression equations between aphid population and daily mean maximum and minimum temperatures during the reproductive stage (50% flowering to physiological maturity) were developed to gain a better understanding. It was found that for 1^{o}C rise in daily mean maximum temperature, the population increased by 51 aphids/10 cm main shoot, and for the 1^{o}C rise in the daily mean minimum temperature, the population increased by 63 aphids/10 cm main shoot.

Keywords: Aphid population dynamics, Mustard cultivars, Temperature

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Effect of Liquid Nano Urea and Coated Urea on Gaseous N Losses and Agronomic Efficiency under Elevated CO_2 and Temperature Interaction

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Ammonium fertilizers suffers major nitrogen losses through ammonia (NH*f*) volatilization and nitrous oxide (N_2O) emissions, leading to low use efficiency. Liquid Nano Urea (LNU) is considered more efficient than traditional soil-applied urea, potentially reducing synthetic N fertilizer use. A two years (2021-2023) wheat crop study conducted to evaluate integrated neem coated urea (NCU) and LNU, NCU alone, and Sulphur coated urea (SCU) under elevated CO_2 and temperature interaction in T-FACE rings to assess gaseous nitrogen losses and agronomic use efficiency (AUE). LNU was applied as two foliar spray in the first year (50% NCU + 2 foliar spray LNU), and as one in second year (75% NCU + 1 foliar spray LNU). Elevated CO_2 (seasonal average 580-585-ppm CO_2) and elevated temperature (seasonal average +1.68-1.74^{O}C over ambient), significantly ($p<0.05$) increased N, O and NH*f* emissions in all treatments compared to ambient (AMB). NH*f* was non-detectable post-LNU foliar application. Integrated LNU+NCU showed lower NH*f* and N, O losses, SCU and NCU differed significantly in NH*f* loss. Soil NH_4^+ was the highest with SCU under AMB, and reduced under elevated temperature (ET) and elevated CO_2 and elevated temperature (ECT) interaction. Wheat yield increased under elevated CO, (EC) but declined under ET in all treatments. Microbial biomass carbon and nitrogen increased significantly under ECT. The decrease in grain N concentration under EC was the lowest with SCU. AUE declined under ECT in all treatments. Despite lower yields, LNU+NCU had higher AUE due to lower N application and reduced NH_4 and N_2O losses. Optimization of LNU application timing and rate is needed to improve wheat yield while maintaining high efficiency.

Keywords: Liquid nano urea, Coated urea, Elevated CO_2, Temperature interaction

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Prediction of Wheat Yield from Soil Health Indicators using Machine Learning Approaches

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Utilizing machine learning approaches to predict wheat yield from soil health indicators can significantly enhance farming practices by providing data-driven insights. By fine-tuning models and choosing the correct machine learning technique, farmers can optimize inputs such as water, fertilizers, and crop management. The objective of this study was to compare four artificial intelligence (AI)-based machine learning techniques, i.e., support vector machine (SVM), artificial neural network (ANN), classification and regression trees (CART) and random forest (RF) as well as multiple linear regression (MLR) in prediction of wheat yield from 11 soil health indicators, i.e., soil organic carbon, pH, EC, available N, P, K, bulk density, porosity, microbial biomass carbon, dehydrogenase activity, and available water content. The combined dataset, i.e., ANN with three hidden layers, outperformed other models in predicting wheat crop yield. Among the various SVM kernel functions, the radial basis function (RBF) demonstrated superior statistical performance on both the training and test datasets compared to the sigmoid, linear, and polynomial kernel functions. Although the performance of MLR, RF, and CART was lower than that of the ANN, all models identified soil pH as the most critical soil health indicator affecting wheat yield.

Keywords: Machine learning, Artificial neural network, Crop yield, Support vector machine, Soil organic carbon, Random forest, soil health

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A Scalable Canal Automation Model for Climate-Smart Water Management

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The Darpanarayanpur Minor Irrigation Project (MIP) was implemented as a pilot canal automation initiative to enhance irrigation efficiency, irrigation water conservation, and climate resilience in a minor irrigation system. The project covered about 285 ha of command area and involved automation of the canal network through real-time monitoring of water levels and automated regulation of canal gates. This system was integrated with demand based irrigation scheduling depending on crop water requirements and effective rainfall. Complementary irrigation water conservation measures, including field channels, bund strengthening, and improved on-farm water management were integrated with canal operations to reduce conveyance and application losses. Post-automation assessments indicated an improvement in conveyance efficiency by about 30%, while head-tail water distribution reliability increased by 36% and 64%, respectively. Assured irrigation coverage increased from about 65% to over 95% in tail-end of the command area, establishing resilience to seasonal rainfall variability and dry spells. Crop diversification was promoted as a climate risk mitigation strategy, with the area under pulses, oilseeds, and vegetables. Water productivity improved by 34%, and average farmer income increased from Rs. 64,000/ha/year to about Rs. 1,02,000/ha/year. The project strengthened participatory irrigation management by enabling data-driven decision making by the Water User Association. The Darpanarayanpur MIP canal automation initiative demonstrated integration of smart canal operations with irrigation water conservation that could reduce climate risks with improvement of water productivity. Thus, the initiative under the study offered a scalable model for replication in similar agro-climatic regions.

Keywords: Scalable canal automation model, Climate-smart water management, Irrigation

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Precision Nutrient Indexing: A Tool for Balanced Fertilizer Recommendations in Acidic Soils of West Bengal

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Soil fertility evaluation and Nutrient Indexing (NI) are pivotal for sustainable agricultural planning and optimizing crop productivity. This study assesses the chemical properties and fertility status of soils in two distinct agro-climatic regions of West Bengal: The Red and Laterite Zone (Birbhum district) and the Terai Zone (Jalpaiguri district). A total of 194 surface soil samples (0-20 cm depth) were collected from representative blocks and analyzed for pH, Electrical Conductivity (EC), Oxidizable Organic Carbon (OC), and available Nitrogen (N), Phosphorus (P), and Potassium (K).

The results revealed significant variability in soil reaction; Birbhum soils ranged from strongly acidic to neutral (pH 4.26–6.94), while Jalpaiguri soils were predominantly extremely to slightly acidic (pH 4.31–6.32), likely due to high Fe and Al oxide content and leaching. Nutrient Index analysis indicated that Nitrogen is the primary limiting factor, categorized as 'Low' in Birbhum and 'Low to Medium' in Jalpaiguri. Conversely, OC, P, and K generally fell into the 'Medium' to 'High' categories across both districts. Statistical analysis demonstrated a significant positive correlation between all nutrient indices and Kharif rice yield (t. ha^{-1}), with NI-Nitrogen showing the strongest correlation. A multiple regression model (R^2=0.973) was developed to predict yield based on soil chemical parameters:

$$Y = 2.492 - 0.129(pH) + 1.927(OC) + 0.004(N) - 0.004(K)$$

The study concludes that current soil management practices, including imbalanced fertilization, have led to specific nutrient deficits. The findings advocate for the adoption of Site-Specific Nutrient Management (SSNM) and balanced fertilization strategies—specifically increasing nitrogen application while optimizing P and K inputs—to enhance soil health and crop yields in these zones. Soil fertility maps were generated with soil parameters such as pH, EC, organic carbon, N, P and K values using geo-statistical procedures followed by kriging method. Nutrient mapping revealed that while Birbhum district is predominantly characterized by a Low-Medium-Medium (N-P-K) status, Jalpaiguri exhibits greater fertility variation, ranging from Low-Medium-Medium to Medium-High-Medium across its diverse blocks.

Keywords: Nutrient indexing (NI), Site-specific nutrient management (SSNM), Chemical properties, *Kharif* rice yield

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Crop Diversification for Enhancing Water Productivity and Sustainability of Millet based Production System in Tribal Dominant Hill Regions of Odisha

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Next to rice, millets are considered as second most important nutrient–rich cereal grains and plays vital role to meet the food and nutritional requirement of the tribal and weaker section of the people in Odisha. Millets are cultivated in 2.64 lakh ha with annual production of 3.31 lakh ton of food grains and covers about 4% of total area under food crops. Finger millet and small millets are leading crops covering 96% of the total millet area. More than 88% of the total millet area is under rainfed ecology and grown during kharif season. Millets are mostly grown in hill tops, slopes and bottoms or in uplands of high rainfall areas like Koraput, Malakangiri, Rayagada, Gajapati, Ganjam, Kandhamal and other tribal dominant districts of Odisha as pure crop, mixed crop and inter crops. The water productivity of the rainfed millets in high rainfall areas of Odisha is comparatively low as compared to millets in Karnataka and Tamil Nadu. Crop diversification such as better crop establishment methods and followed by short duration pulses in sequence by utilizing winter rainfall of the region can enhance the water productivity and system productivity. In addition a field level case study was conducted at Dharakote and Seragada Blocks of Ganjam districts to identify the most profitable and resource efficient crop establishment method and finger millet based cropping sequence.

Survey findings reveal that line transplanting (LT) significantly enhanced the grain yield and physical water productivity (PWP) of finger millet by 39.8 and 45.8 %, respectively, as compared to line sowing (LS). Similarly, SMI resulted in improvement of grain yield and PWP by 75.4 and 75.0 %, respectively, as compared to line sowing. Intensification of finger millet with horsegram in sequence in light soils under rainfed ecology enhances system yield and water productivity by 95.3 and 80.6%, respectively, as compared to finger millet-fallow. Under medium and heavy soil finger millet-green gram cropping system resulted in increase in system yield and water productivity by 143.3 and 125.8%, respectively. Finger millet–horsegram or green gram can be recommended for enhancing water productivity and farm income under upland rainfed ecology of Odisha.

Keywords: Cropping system, Crop establishment methods, Uplands, Rainfed ecology

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Three-Dimensional Transient Groundwater Flow Modelling of the Lower Mahanadi River Basin (Nayagarh, Odisha) Using MODFLOW-NWT

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Groundwater is the principal source of irrigation and domestic water supply in the lower Mahanadi River Basin, particularly in Nayagarh district, Odisha. Rapid intensification of groundwater abstraction, combined with spatial heterogeneity in recharge and increasing rainfall variability, has placed considerable stress on regional aquifer systems, necessitating robust, process-based groundwater assessment frameworks. This study develops a three-dimensional transient groundwater flow model for the Nayagarh region using MODFLOW-NWT implemented within the GMS 10.7.7 environment to quantify groundwater dynamics and support sustainable resource management under the *Rashtriya Krishi Vikas Yojana* (RKVY). The model represents a two-layer aquifer system comprising an unconfined upper aquifer and an underlying confined aquifer. Major hydrological processes, including spatially distributed recharge, evapotranspiration, river–aquifer interaction, drainage, and groundwater pumping, were explicitly simulated. Hydrogeological parameters were assigned using raster-based inputs and literature-supported ranges, with horizontal hydraulic conductivity varying from 0.094 to 5.0 m/day, vertical anisotropy of 3, specific yield of 0.20, porosity of 0.30, and specific storage of 0.00112. The model domain was discretized into 4,752 grid cells, of which 2,385 were active. Calibration and validation results show strong agreement between observed and simulated groundwater heads, accompanied by excellent numerical stability, reflected by a flow-budget error of 9.86×10^{-7} %. Flow-budget analysis indicates that groundwater recharge constitutes the dominant inflow, while evapotranspiration, river leakage, and drainage represent the principal outflow components. Simulated hydraulic heads decline from northern uplands toward southern low-lying and river-proximal areas, consistent with natural hydraulic gradients. The confined aquifer displays heightened sensitivity to pumping stresses, indicating vulnerability to over-extraction. The model provides a scientifically robust basis for groundwater zoning, regulated abstraction, artificial recharge planning, and climate-resilient water management aligned with Sustainable Development Goal 6.

Keywords: Groundwater flow modelling, MODFLOW-NWT, Aquifer vulnerability, Recharge–discharge dynamics and SDG 6

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Effect of Boron and Zinc on the Growth, Yield, and Quality of Sesame in Red and Lateritic Soils of West Bengal

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A field experiment was conducted to study the effect of boron and zinc on the growth, yield and quality of sesame, which was laid out in Randomized Block Design (RBD) with nine treatments at Agricultural Research Farm, Palli Siksha Bhavana, Visva Bharati University. The nine treatment consisted of two doses of zinc as $ZnSO_4$ (2 and 4 kg ha^{-1}) as soil application and two doses of foliar spray of boron as H_3BO_3 (0.2% and 0.4%) and a combination of both the treatments, along with a control plot. Recommended dose of NPK fertilizer was given as basal dose at the time of sowing in 80:40:40 (Urea, SSP, MOP). Results revealed that the treatment with Zn @ 4 kg ha^{-1}+B @ 0.2% along with the RDF showed superior results as compared to other treatments. There was a significant increase in plant height, chlorophyll content, number of capsules $plant^{-1}$, number of seeds $capsule^{-1}$, test weight with the application of Zn @ 4 kg ha^{-1}+B @ 0.2%. However there was no such significant increase in growth, yield, quality parameters with the increase in boron dose @0.4%. The seed yield, stover yield, biological yield was also increased due to the synergistic effect of Zn @ 4 kg ha^{-1}+B @ 0.2%. The Oil content of sesame was found to be up to 52.33% and the protein content was found to be up to 20.36% with the application of zinc and boron Zn @ 4 kg ha^{-1}+B @ 0.2%. Analysis of the total cost of cultivation, net income and B:C ratio was done and it was found that the treatment with Zn @ 4 kg ha^{-1}+B @ 0.2% proved to provide better profits. Farmers of Red and Lateritic soil may be advocated to apply Zn@4kg ha^{-1}+ B@0.2% along with RDF for the cultivation of sesame for better yield, growth, quality, economic return, and soil health.

Keywords: Zinc, Boron, Biological yield, Oil content, Protein content

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Comparison of Machine Learning and Regression-Based Pedotransfer Functions for Soil Aggregate Stability Prediction

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The soils of India's north-eastern Himalayan belt exhibit low structural resilience, making them vulnerable to erosion by surface runoff during intense rainfall events. Soil Aggregate Stability (SAS) is a critical indicator of soil quality, as it represents the soil's capacity to resist disintegration and erosion. Mean Weight Diameter (MWD) is a widely used quantitative index of SAS. However, direct determination of MWD using wet sieving is laborious, time consuming, and impractical for large scale assessments. Information on soil aggregate stability in the north-eastern Himalayan region remains limited, underscoring the need for alternative estimation methods. Accordingly, this study aimed to develop pedotransfer functions to estimate MWD from easily measurable soil physical and chemical properties using machine learning (ML) techniques. Three ML models, namely Artificial Neural Network (ANN), Random Forest (RF), and Support Vector Machine (SVM), were developed and compared with a conventional Multiple Linear Regression (MLR) model. A total of 132 surface soil samples from 0–15 cm depth were collected from a selected watershed in Sikkim using a stratified random sampling approach across two dominant land use systems, agricultural land and forest land. Standard laboratory analyses determined bulk density, soil pH, organic carbon, sand, silt, clay, calcium and magnesium ion, and carbonate and bicarbonate ions. Mean Weight Diameter was measured using the wet sieving technique. The dataset was divided into training (80 %) and testing (20 %) subsets, and model stability was examined using K-fold cross validation. Model performance was evaluated using R squared, RMSE, MAE, NSE, and AIC. Overall, ML models showed superior predictive ability compared to MLR. RF performed best for agricultural soils, ANN for forest soils, and SVM for combined datasets. While model performance varied, SVM showed the highest robustness.

Keywords: Soil erosion, Soil aggregate stability, Land use, Random forest, Artificial neural network, Support vector machine

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Development and Performance Evaluation of a Kinetic Energy based Spiral Tube Water Wheel Pumping System (STWWPS)

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Developed STWWPS is one of the non-conventional (Powered by the kinetic energy of flowing water) water pumping system for pumping water or similar liquid without use of electric or any other fuel. It is a self-supporting pumping system for lifting water from canal; stream/nallah, provided suitable site conditions are met out. This system requires only flowing water, where the movement of water produces kinetic energy that can be harnessed for useful work such as pumping/irrigation. Float, inlet, blade, spiral tube, bearing, housing, union valve, T-joint, and outlet are the key components of the STWWPS. When the kinetic energy of flowing water directly strikes on the blade, resulting thrust of the blade causes the wheel to continuously rotate in the direction of water flow. Water enters the inside of the spiral tube through the inlet valve, and it is move through the tube by wheel's turn. During this process, alternating column of water and air is formed inside the tube with each rotation. Air being compressible forces the water to exit through the outlet. Performance and testing of the water wheel were conducted under different delivery heads and horizontal conveying distances, both adversely affect the rate of discharge. Experimental results show that water discharge ranges from 0.59 to 0.44 lps at delivery heads of 4.14 to 4.83 m and horizontal distances of 3 to 10 meters. The developed pumping system can gave a discharge of 55,296 lpd at 1 m water depth, 2 m/s velocity, 4.28 m lifting head, and carrying distance of 3 m. The cost of developed pumping system 51,200 liters of water at operating head of 3 m was obtain to be Rs. 260.15, 287.83, 760.43, and 1604.74 for STWWPS, electrical power, diesel power, and human power pumping system, respectively.

Keywords: Delivery head, Discharge, Lifting water, Kinetic energy, Water wheel

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Crop Demand Driven Site Specific Nitrogen Management in Rainfed *Kharif* Rice (*Oryza sativa* L.)

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A field experiment was conducted during *kharif* at Agronomy Main Research Station, OUAT, Bhubaneswar to study "Crop demand driven site specific nitrogen management in rainfed *kharif* rice". The experiment was laid out in randomized block design replicated thrice with ten treatments. The soil of the experimental plot was loamy sand with pH 6.2, organic carbon 0.57%, EC 0.125 ds m^{-1}, available N 168.2 kg/ha, available phosphorus 25.3 kg/ha and available potassium 193.8 kg/ha. The crop variety tested was "Maudamani". The study revealed that basal application of 20 kg N/ha along with 30 kg N/ha at tillering at SPAD ≥ 35 + 20 kg N/ha at panicle initiation at SPAD ≥ 35 produced the significantly higher seed yield of 4632 kg/ha. This indicated a saving of 10 kg N/ha with maximum recorded yield. At this level of production and nitrogen management, the crop removed 88.1 kg N/ha and recorded higher agronomic N use efficiency (34.4 kg grain/ kg N applied), more N recovery (58.4%) higher partial factor productivity of N (66.1 kg grain/ kg N applied) and higher benefit-cost ratio (1.91) in comparison to other treatments. Very little improvement in soil available N and P while depletion of available K were noticed in that treatment.

Keywords: Nitrogen management, SPAD, LCC

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Flood Assessment and Its Impact on Natural Resource Management in Flood Prone Areas of Eastern Region of Odisha

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Flood-prone landscapes are increasingly challenged by recurrent flooding and waterlogging, posing serious threats to agricultural productivity and sustainable natural resource management. This study presents an integrated geospatial and soil fertility assessment to evaluate flooded and waterlogged areas and their implications for site-specific nutrient management. The primary objective was to delineate flood-affected zones, analyze soil physicochemical and nutrient characteristics, and recommend optimized fertilizer requirements to enhance crop productivity. The study was conducted in Lokapala village, Kanas block of Puri district, Odisha, India, covering 549 ha. Open-source Digital Elevation Models (SRTM, ALOS-PALSAR, ASTER, and NASA DEM) were assessed to characterize terrain-driven hydrological variability. Sixty-four geo-tagged soil samples were collected across three topographic positions—upper, middle, and lower ridges—and analyzed for pH, electrical conductivity, soil organic carbon, and available nitrogen, phosphorus, and potassium. Spatial distribution maps of elevation, slope, and soil nutrient parameters were generated using ArcGIS with the Inverse Distance Weighting (IDW) interpolation technique. Results revealed that water-logging predominated over flooding, affecting average areas of 297.36 ha and 231.65 ha, respectively. Among the evaluated datasets, SRTM DEM (1 arc-second resolution) demonstrated superior suitability for regional-scale agricultural and hydrological analysis. Fertilizer recommendations varied spatially with topography: nitrogen requirements in the upper ridge ranged from 0–109 kg ha^{-1}; potassium requirements ranged from 0–70, 0–62, and 0–72 kg ha^{-1} in the upper, middle, and lower ridges, respectively; phosphorus requirements ranged from 531.0 to 581.2 kg ha^{-1} across all ridge positions. The study underscores the value of integrating high-resolution geospatial data with soil test–based nutrient assessment to optimize fertilizer application, enhance crop productivity, and support sustainable agricultural management in flood- and water logging-prone regions

Keywords: Floods, Waterlogged area, Flooded area, SRTM DEM, Fertilizer application

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Groundwater Recharge as a Catalyst for Green Agriculture: Evidence from an RKVY Intervention

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Groundwater recharge interventions are increasingly emphasized under public investment programmes in India to address declining groundwater levels and enhance agricultural sustainability. However, the long-term success of such interventions depends not only on recharge efficiency but also on the productive and sustainable utilization of the recharged groundwater at the farm level. This study examines the outcomes of integrating groundwater recharge with crop diversification under the *Rashtriya Krishi Vikas Yojana*–Groundwater Recharge (RKVY–GWR) project implemented in Sajanapada village of Nayagarh district, Odisha. The intervention focused on promoting collective and productive use of recharged groundwater by linking recharge structures with high-value crop planning. A group of 25 women farmers jointly cultivated one acre of flower crop using recharged groundwater during a three-month cropping period. Prior to the intervention, the land remained uncultivated due to the absence of assured irrigation, resulting in zero agricultural income. The introduction of supplemental irrigation through groundwater recharge enabled timely crop establishment and improved water availability during critical growth stages. Economic analysis revealed that the collective cultivation incurred a total input cost of ₹ 10,000 per acre, which included expenses on land preparation, irrigation, fertilizers, and labour. The intervention generated a net return of Rs. 17,000 per acre within a single cropping season, demonstrating a substantial income gain over the baseline condition. The results highlight the potential of recharged groundwater to support crop diversification toward high-value crops, improve water productivity, and enhance livelihood opportunities, particularly for women farmers. The findings suggest that groundwater recharge investments yield greater economic and social benefits when explicitly linked with context-specific crop planning and collective farming approaches. Such integration not only improves the utilization efficiency of recharged water but also reduces individual risk and enhances resilience in groundwater-dependent regions. The study provides evidence that coupling groundwater recharge interventions with diversified crop systems can serve as a scalable and sustainable pathway for promoting green agriculture and rural livelihoods in water-stressed areas.

Keywords: Groundwater recharge, Crop diversification, RKVY, Odisha

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Influence of Irrigation Management and Different Mulches in Regulating Soil Hydro-Thermal Properties under Cabbage Crop

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Efficient irrigation management and the use of mulches are important agronomic practices for conserving soil moisture, regulating soil temperature, and improving crop productivity, particularly under conditions of increasing water scarcity and climate variability. Irrigation directly controls soil water availability, while mulches modify the soil physical condition and surface microclimate by altering evaporation, moderating temperature, and improving soil plant water relations. For understanding their combined influence on soil hydro-thermal behavior a study was undertaken with various water application rates through drip and different mulch (Black, Silver plastic and paddy straw) materials in cabbage crop. The result from the experiment revealed that surface soil layer (0–15 cm) maintained the highest moisture under 100 % irrigation (27.7%), followed by 80 % (23.5%) and 60 % irrigation (21.5%), showing a clear decline with reduced water application. Similar trends were observed at the 15–30 cm depth, although differences were statistically non-significant. Among mulch types, silver mulch retained the highest surface soil moisture (25.8%), followed by black mulch (24.7%) and paddy mulch (22.2%). The higher reflectivity of silver mulch likely reduced evaporative loss, maintaining better soil water availability. Soil temperature exhibited an inverse relationship with soil moisture, with elevated temperatures under deficit irrigation and non-mulched conditions. Paddy straw mulch effectively moderated soil temperature by reducing radiant heat load and conserving moisture, while silver mulch reflected incoming solar radiation, resulting in comparatively lower surface temperatures during peak hours. The combined influence of irrigation and mulch treatments thus played a crucial role in maintaining favorable soil hydrothermal regimes for crop growth with paddy mulch recording the highest yield (36.17 t ha^{-1}), followed by black (34.53 t ha^{-1}) and silver mulch (33.48 t ha^{-1}). The highest dry matter (3.66 t ha^{-1}) and yield (36.15 t ha^{-1}) were observed under 100% irrigation, which were statistically similar to 80% irrigation (3.37 t ha^{-1} and 37.55 t ha^{-1}, respectively). Yield declined significantly under 60% irrigation (30.48 t ha^{-1}). Irrigation application combined with suitable mulching proved effective in maintaining favourable soil hydro-thermal conditions.

Keywords: Soil hydro-thermal, Irrigation management, Plastic mulch, Paddy straw mulch, Cabbage yield

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Rainwater Management in Clayey Soil

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Clayey soils are present in low (<500 mm) to high rainfall (>1000 mm) areas and different climatic conditions. So, rainwater management option in clayey soils is site specific to some extent. Fine particles in clay cause slow absorption, surface sealing and waterlogging risk. Rainwater management in clayey soil includes slowing runoff, and improving infiltration rate and soil structure. Key management strategy include creating shallow channels to guide water for safe disposal as in Broadbed and furrow (BBF) method. The surplus water should be harvested in farm pond after passing through a grassed channel to reduce the velocity and soil loss. Preventing compaction is desired to promote water retention and reduce loss. It can be achieved by doing tillage and cultural operations at appropriate soil moisture content. However, vertisols known as 'hour minute clay' gets limited tillage opportunity time and so, it should be completed soon using efficient implements. Improving soil structure is another management strategy for balancing soil aeration and water retention. Adding enough organic matter, promoting earthworm and microbial activity, crop rotation with deep rooted crops, avoiding wet tillage and heavy implements, zero and reduced tillage, natural farming, and agroforestry using suitable species are some important means for improving soil structure and water retention. In clayey soil, surface sealing and crust formation leads to the problem of seedling emergence. The problem can be avoided by sprinkling water on soil surface.

In coastal waterlogged areas, 'Alternate raised and furrow bed and aquaculture in agroforestry system' can be practiced with high economic and biodiversity gains. Also, 'Permanent raised bed and pond with undisturbed field in between', and 'Integrated crop-fish farming system' are profitable and promote crop diversification. However, wide adoption of these land modification options is not happening due to fund constraints, little concern for environmental benefits and farmers' unwillingness to divert paddy land for other uses. In riverine flood affected areas, sand deposit and soil erosion leads to land degradation (NITI Aayog, 2021). Farmers in Kanas Block of Puri district in Odisha and other areas, add these sands to nearby fields with clayey soils and improve the texture. With the improved texture, harvested nutrient from flood water and improved water supplying capacity of soil, such fields are used for growing profitable crops (vegetables, water melon and groundnut) in post-rainy season. It is useful to construct a farm pond in clayey soil due to very low rate of seepage percolation loss (2 to 3 mm/day). Recently, use of soil moisture sensors are proposed as an aid in water management. However, careful selection and calibration of sensors is needed due to high water-holding capacity and variable pore structure of clayey soils. Capacitance-based sensors perform with good accuracy. Gypsum-based and tensiometer based sensors are inferior due to salinity interference and slow response. Time domain reflectometry (TDR) sensors are useful, but cost prohibitive. In conclusion, clayey soils are generally considered as difficult to manage for crop production, but agrotechniques are available to efficiently manage these soils for improved water and nutrient use efficiency.

Keywords: Land modification, Problem soils, Sensors, Soil structure, Texture

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Enhancing Climate Resilience through Agromet Advisory Services: Challenges

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Weather is a fundamental driver of agricultural productivity, influencing every stage of crop growth, development, and yield formation. Its pronounced spatial and temporal variability exposes farming systems to substantial risk; however, timely and reliable weather forecasts enable farmers to reduce losses through informed planning and management of agricultural operations. Key weather variables such as rainfall, temperature, and humidity strongly regulate crop performance as well as pest and disease dynamics. By integrating historical weather data with short- and medium-range forecasts, advance warnings of potential pest and disease outbreaks can be generated, allowing farmers to implement preventive and corrective measures at appropriate times. Weather-based agromet advisory bulletins translate forecast information into crop- and location-specific recommendations related to irrigation scheduling, nutrient management, and pest and disease control. Adoption of these advisories improves input-use efficiency, reduces unnecessary irrigation and chemical applications, lowers production costs, and enhances crop yields, thereby increasing farm profitability. Climate variability and the increasing frequency of extreme weather events pose serious challenges to agricultural productivity, rural livelihoods, and food security, particularly in climate-sensitive regions. In this context, agromet advisory services have emerged as a vital decision-support mechanism for enhancing farm-level climate resilience by converting weather and climate information into actionable management guidance. Despite notable improvements in forecasting skill, observational infrastructure, and digital dissemination platforms, the effectiveness of agromet advisory services remains constrained by persistent challenges related to knowledge gaps, limited data integration, weak institutional coordination, and uneven adoption by end users. Indian agriculture is especially vulnerable to extreme events such as heat waves, cold spells, droughts, floods, and unseasonal rainfall. The Gramin Krishi Mausam Sewa (GKMS) programme represents one of the largest operational agromet advisory systems globally, delivering regular advisories through coordinated efforts of meteorological, agricultural research, and extension institutions. While GKMS has achieved wide outreach, its impact is limited by inadequate spatial and temporal downscaling of forecasts to match farm-level decision requirements, insufficient integration of weather information with crop phenology and local management practices, and uneven uptake across regions and socio-economic groups.

Keywords: Climate resilience, Agromet advisory services, Challenges

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Performance of Resource Conservation Technologies for Sustainable Winter Sunflower Production in Eastern India

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Sunflower is increasingly being introduced as a non-traditional winter crop in eastern India; however, its productivity is frequently constrained by low soil moisture, highlighting the need for efficient irrigation strategies. Resource conservation technologies (RCTs), such as zero tillage, surface residue retention, and water-efficient irrigation methods, have the potential to improve resource-use efficiency while reducing environmental impacts. A three-year field experiment (2021–2024) was conducted at Bhubaneswar, India, to assess five RCT-based treatments with residue retention alongside a conventional practice: zero-till subsurface drip irrigation (z-sd-r), zero-till surface drip irrigation (z-d-r), permanent broad-bed furrow (p-bbf-r), permanent narrow-bed furrow (p-nbf-r), zero-till flood irrigation (z-fbf-r), and conventional tilled flood irrigation (ct-fbf; control). Treatments were evaluated for seed yield, economic returns, and energy, carbon, and water footprints. Sunflower productivity, profitability, and all footprint indicators were significantly affected by RCTs ($p < 0.001$). The z-sd-r treatment recorded the highest seed yield (2146 kg ha^{-1}) and net returns (998 USD ha^{-1}), along with 13% lower carbon inputs and 45% reduced water use compared to the conventional control. Drip-based RCTs (z-sd-r and z-d-r) consistently outperformed surface irrigation–based systems (p-nbf-r, p-bbf-r, and z-fbf-r), achieving 48% greater net energy output, 21% higher net carbon output, approximately 26% lower specific energy consumption, and a 23% lower carbon footprint. These gains were largely attributable to reduced diesel and electricity use. Overall, the integration of subsurface drip irrigation, residue retention, and zero tillage emerged as the most resource-efficient and climate-smart strategy for winter sunflower production in moisture-stressed uplands of eastern India and comparable agroecosystems globally.

Keywords: RCT, Sunflower, Water productivity, Carbon footprint, Eastern India

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Effect of Different Tillage, Nutrient Doses and Residue Management on Soil Organic Carbon and Physical Properties under Conservation Agriculture

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A field experiment was conducted to study the effect of tillage practices (No tillage-NT, Reduced tillage-RT and Conventional tillage-CT) along with residue retention (30 cm and 60 cm height) and different nutrient doses (75% RDF, 100% RDF and STCR) on soil organic carbon and physical properties of Vertisol at research farm of ICAR-Indian Institute of Soil Science, Bhopal. In order to understand the impact of different management practices soil samples were collected and analyzed after 4 crop cycles. Soil organic carbon (SOC) is a measurable component of soil organic matter and plays an important role in determining the physical, chemical and biological properties of soil. Study results showed that the tillage system was found significant impact on SOC in the end of *kharif* season sampling at different soil depths. SOC was significantly higher (0.78%) under NT plots with both 30 and 60 cm residue height at near the surface (0-10 cm) while at sub-surface maximum (0.55%) under NT and RT (with 30 cm residue height) in the end of *kharif* due to higher residue addition and minimum soil disturbance. The results of the experiment demonstrated that adoption of NT or RT along with 60 cm and 30 cm residue retention showed maximum drop in bulk density (BD) and improvement in large macroaggregate (LMag) and small macroaggregate (SMag) indicating the favourable effect of Conservation tillage practices and residue retention on improvement in physical properties of Vertisol. The soil moisture content was also showed significantly higher values under NT and RT and residue retention treatments than conventional tillage (CT) system. The results indicated that soil aggregation measured via mean weight diameter (MWD) of soils (0-10 and 10-20 cm depth) recorded highest (1.56 and 1.43 mm) in the NT (with 60 cm residue height) and RT (with 30 and 60 cm residue height) whereas the lowest value was recorded in the CT at 0-10 and 10-20 cm depth of the soil (1.13 and 1.20 mm). Similarly, the maximum percentage of WSA (82.14 and 78.14%) at 0-10 and 10-20 cm soil depth, was recorded under NT with 60 cm residue height retention. The impact of nutrient management practices was not found effective in improving the physical properties of Vertisol. It was concluded that adoption of NT or RT along with 60 cm residue retention is the best strategy to improve the soil organic carbon and physical health of the Vertisol of Central India.

Keywords: Tillage system, Residue and nutrient management, Soil organic carbon, Physical properties

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Evaluation of Soil Erosion Risk in the Lower Tapi Basin Using NDVI-Derived C Factor

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Soil erosion is a major environmental concern, and its accurate estimation is essential for sustainable land and water resource management. Among the parameters influencing soil erosion models, the crop/cover management factor (C) plays a critical role by representing the protective effects of vegetation and ground cover. Remote sensing–based vegetation indices, particularly the Normalized Difference Vegetation Index (NDVI), provide an effective means to quantify spatial variations in vegetation cover. This study evaluates soil erosion risk in the Lower Tapi Basin, Gujarat, India, through the estimation of the C factor derived from NDVI. NDVI was computed using IRS P6 LISS III satellite imagery. The NDVI map was subsequently utilized to generate a spatially distributed C factor map using regression equations implemented in the Spatial Analyst tool of ESRI-ArcGIS. Three approaches were employed to estimate the C factor: the De Jong method, the Van der Knijff method, and direct correlation between NDVI and C factor values. The results indicate that the average C factor values obtained from the De Jong and Van der Knijff approaches are 0.3168 and 0.6195, respectively, while the NDVI–C factor correlation method yielded a higher value of 0.7472. The NDVI-based correlation approach was found to better represent real-time field conditions and was therefore adopted for further analysis. The estimated C factor was integrated into the Universal Soil Loss Equation (USLE) to assess annual soil loss in the basin. The total soil loss was estimated to be 4154.46 tons per year, with a crop coefficient of 0.33, indicating significant erosion risk. The findings highlight that rapid deforestation and reduction in vegetation cover have intensified soil erosion and increased reference evapotranspiration in the study area. The study demonstrates the effectiveness of NDVI-derived C factors for evaluating soil erosion risk and supports their application in conservation planning.

Keywords: NDVI, Soil erosion, C factor, Remote sensing, USLE

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Assessing the Impact of Unplanned Urbanization on Land Surface Temperature and Habitat Suitability in Cuttack City, India: A Spatial Analysis from 1990 to 2020

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Unplanned urbanization causes an increase in land surface temperature (LST) and adversely affects the climate and environment within cities. Cuttack City, India, is experiencing rapid urbanization at an alarming rate, facing particular environmental challenges and hosting critical ecosystems that require protection. This study uses the Urban Growth Suitability Index (UGSI) to determine which parts of the city are Suitable and which are unsuitable for habitation based on the geographic distribution of heat vulnerability surrounding Cuttack City from 1990 to 2020. Using a mono window method, the LST for 1990, 2000, 2010, and 2020 is derived from the Landsat 5, Landsat 7, and Landsat 8 satellite data. A simple linear regression model has been used to establish a trend in the relationship between LST and land use/ land cover (LULC), similar to UGSI with LST. Finally, the most Suitable and Unsuitable regions for habitation in Cuttack City are marked using UGSI. The findings indicate that the highest temperature in the city was 32.07°C in 1990 and increased to 38.67 °C in 2020. This is due to the decrease in city vegetation area by 51.39% and the expansion of the urban area by 58.19%. The core region of the city shows higher temperatures than the urban fringes, where vegetation cover is scanty or has no greenery. Out of 59 administrative wards (Municipal administrative regions) in Cuttack City, 27 experienced acute temperatures due to sparse vegetation cover and an intense built environment. A total area of 15.99 km^2 of Cuttack City facing this heat vulnerability accounts for 19.61% of the total City area, which is highly unsuitable for habitation, and 10.77 km^2 of Cuttack City, which accounts for only 13.21% of the city area are Suitable for habitation. This study will help city planners by guiding actions to protect residents from the adverse effects of extreme heat.

Keywords*:* Unplanned urbanization, Land surface temperature, Cuttack, Spatial analysis

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Vertical Distribution of Available Plant Nutrients in Parjang Block of Dhenkanal District in Mid Central Table Land Agroclimatic Zone of Odisha

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Evaluation of available plant nutrient status of soil samples collected on GPS basis has greater use because not only it gives an idea about fertility status of the soil of a particular area but also helps in monitoring the soil health and recommendation of proper fertilizer dosage in the area under study over a period of time. The present investigation was carried out in Parjang block of Dhenkanal district located in the Mid Central Table Land Agroclimatic Zone of Odisha. Surface soil samples were collected from different villages and profile samples were collected from two representative pedons (upland and low land) of Parjang block to evaluate the vertical distribution of available plant nutrients and to prepare GPS based soil fertility map of the study area. The soil texture of the pedons varied from sand to sandy clay loam with clay content variation of 8.2-23.8%. The soil pH values ranged from 4.50 to 7.42 indicating acidic to neutral soil reaction. The soils are mostly non saline and organic carbon content varied from 0.13 to 1.92% showing low to high status. The available Nitrogen, Phosphorus and Potassium (NPK) content ranged from 100 to 336, 0.24 to 19.60 and 70.56 to 840 kg ha^{-1} respectively indicating both deficiency and sufficiency status in the study area. The available Sulphur (S) and Boron (B) content varied from 3.15 to 69.65 and 0.13 to 1.61 mg kg^{-1} respectively. The analysis of profile samples revealed distinct variation in soil properties across different horizons. Soil fertility map provides a clear information regarding the nutrient status, identifying soil related crop production constraints and also helps in recommending suitable crops for the area and application of fertilizer dosage as per soil test value for better soil health and sustainability.

Keywords: Soil fertility, Available plant nutrients, Soil health, Crop production constraints, NPKS and B

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Modelling Approaches for Predicting Soil Carbon Dynamics in Long-Term Fertilizer Experiments under Changing Climatic Scenarios in India

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A carbon (C) is the soul of soil and plays crucial role in maintenance of soil fertility. The soil organic carbon (SOC) sequestration plays a pivotal role in improving soil health and mitigating climate change. The present study aimed to assess the SOC sequestration potential as influenced by different crops/cropping systems and nutrient management practices under a long-term fertilizer experiments (LTFEs) at Jabalpur, Palampur and Ranchi using process-based modelling approaches. Long-term fertilizer experimental data on crop yield and nutrient management practices were used to simulate SOC dynamics and quantify carbon sequestration potential over time. Model simulations revealed a positive impact of integrated nutrient management (100% NPK+FYM) practices on SOC stocks compared to other treatments in LTFEs. The simulated results indicated an increase in SOC sequestration under integrated nutrient management showed SOC enhancement under different RCP scenarios compared other nutrient options. A graphical analysis of model outputs (RCP scenarios) demonstrated a gradual accumulation of SOC with time, particularly under treatments receiving organic manure with inorganic fertilizers. The trends depicted in the graphs highlight the role of sustained carbon inputs and improved nutrient use efficiency in enhancing soil carbon storage. The modelling results further suggested that nutrient management and cropping system significantly influenced carbon turnover rate and stabilization of SOC pools. Overall, the study emphasizes that long-term adoption of integrated nutrient management coupled cropping system can substantially enhance SOC sequestration. The findings underscore the utility of modelling approaches as effective tool for predicting long-term soil carbon dynamics and guiding sustainable nutrient management strategies under changing climatic scenarios.

Keywords: Dynamics, Integrated nutrient management, Long term fertilizer experiments, Model, Sequestration, Soil organic carbon

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Rice Water Productivity Mapping for Lawan Command Area using CROPWAT 8.0 Model and GIS

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Water is crucial for agriculture, surpassing even soil in importance, and is essential for life, food production, and economic growth. Increasing demand due to population growth and higher living standards has led to significant water scarcity issues. The study area lies in semi-arid tract, the Lawan Command Area (LCA: 2965 ha) Chhattisgarh state of India. To address this, the study focuses on mapping rice water productivity in the Lawan Command Area (LCA) using the CROPWAT 8.0 model and GIS, analyzing 20 years of meteorological data and rice crop coefficients to estimate evapotranspiration, with productivity data sourced from the Agriculture Department of Chhattisgarh. This is in conformity with the local rice crop circumstances (variety: Swarna sub-1). The crop under consideration in this study is rice, which is mostly grown in command areas during the *Kharif* season. The results indicate that 20 years average crop water productivity (CWP) in the entire command area was found to be 0.61 kg m^{-3}, varying from a minimum of 0.26 kg m^{-3} in the year 2017 to a maximum of 0.74 kg m^{-3} in the year 2007. Average field water productivity (FWP, considering percolation losses) in the command area was found to be is 0.34 kg m^{-3}, varying from a minimum of 0.15 kg m^{-3} and maximum of 0.41 kg m^{-3} in the same year. Similarly, over the average of 20 years and 13 different villages in the study area, the maximum CWP was found as 0.626 kg m^{-3} in village *Sundry* while the minimum was found as 0.578 kg m^{-3} in village *Harinbatta*. Maximum FWP was found as 0.352 kg m^{-3} in village *Sundry* while the minimum was found as 0.325 kg m^{-3} in village *Harinbatti*. There is significant difference between CWP and FWP, this calls for urgent actions to reduce losses in the field.

Keyword: Water productivity, Consumptive water use, Reference evapotranspiration, CROPWAT

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Soil Texture Estimation from SAR and Optical Remote Sensing with Random Forest and Ordinary Kriging

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Rapid, non-destructive estimation of soil textural fractions is increasingly pursued as an alternative to conventional, labour-intensive laboratory methods. This study investigates a hybrid modelling framework integrating random forest (RF) and ordinary kriging (OK) to estimate soil sand and silt content using remote sensing data. A total of 128 surface soil samples collected from Paschim Medinipur and South 24 Parganas districts of West Bengal, India, during the pre-kharif seasons of 2023–2024 were used for model development and validation. Twenty-two predictor variables were utilized, encompassing parameters derived from Sentinel-1 and Sentinel-2 data, SAR-based indices, terrain attributes, and key climatic factors. A spherical semivariogram model was selected for Ordinary Kriging, as it provided the best fit to the residual spatial structure. Results indicate that the hybrid RF+OK model outperformed the standalone RF model, achieving lower RMSE values of 6.01 for sand (≈1.5 % improvement over RF at 6.10) and 5.76 for silt (≈13 % improvement over 6.59), along with reduced MAE for sand (3.83 vs. 3.99) and silt (4.61 vs. 5.63). The hybrid model also showed improved correlation with observations for both sand (0.93 vs. 0.92) and silt (0.91 vs. 0.90). These findings highlight the benefits of integrating machine learning with geostatistical residual correction and demonstrate the potential of SAR–optical data fusion for spatially detailed soil texture mapping.

Keywords: Sand, Silt, SAR, Random forest

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Drought Trends and Teleconnections over Agro-Climatic Zones of India

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Spatiotemporal trends of meteorological drought were examined in Agro climatic zones (ACZs) of India using the Standardized Precipitation Index (SPI) and the graphical Innovative and conventional trend detection methods. The relationship of monsoon-season drought over ACZs with El Niño–Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD) was also investigated. Analysis of September SPI-4 indicated nearly equal percentage of wet (SPI > 0; 49.9%) and dry (SPI < 0; 51.1%) years. Monsoon drought occurrence ranged between 12.5% and 18.3% across ACZs. Trend slopes of monsoon SPI-4 varied from "0.14 to 0.11/10a. Long-term trend analysis of monsoon SPI-4 revealed significant drying tendencies over central, northern, and eastern India, whereas most of peninsular India exhibited wetting trends, except for the western coastal plains, which showed pronounced drying. Monsoon SPI-4 displayed a strong association with ENSO, while its linkage with the IOD was very weak. These findings indicate that ENSO is the primary driver of drought variability in India's ACZs, with the influence of the IOD being marginal.

Keywords: SPI, ITA, Mann-Kendall, Sen's slope, ENSO, IOD

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Delineation and Mapping of Nutrient Status for Fertility Management of IIWM Research Farm, Odisha

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Precision agriculture relies heavily on the accurate assessment of soil spatial variability to optimize resource use. A comprehensive study was conducted at the ICAR-IIWM Research Farm, Mendhasal, Odisha, to evaluate soil fertility and delineate nutrient management zones (MZs) using geospatial techniques. A total of 188 geo-referenced soil samples were systematically collected from two depths: surface (0–15 cm) and subsurface (15–30 cm). The analysis encompassed physical properties (texture) and chemical parameters, including pH, electrical conductivity (EC), organic carbon (OC), macronutrients (N, P, K), and micronutrients (Zn, Cu, Fe, Mn). The findings revealed a diverse textural range. Surface soils were predominantly coarser, characterized by loamy sand to sandy clay loam (averaging 60% sand and 21% clay). Subsurface layers exhibited a finer texture, ranging from sandy loam to clay, with clay content increasing to 26%. This vertical gradient suggests significant particle translocation through eluviation and illuviation processes. Chemically, the soils were categorized as extremely to slightly acidic, with pH values ranging from 3.91 to 7.10 across both depths. Low EC values (0.02–0.29 dS m^{-1}) confirmed the soils are non-saline. Nutrient analysis indicated significant variability. Organic carbon and available nitrogen were notably higher in the surface layer (OC up to 1.66%; N up to 361.27 kg ha^{-1}) compared to the subsurface. Phosphorus and potassium levels also showed wide fluctuations, while micronutrients—specifically iron and manganese—were found in relatively high concentrations. To visualize this data, thematic maps for thirteen soil parameters were generated using Ordinary Kriging in Python and ArcGIS 10.3. The spatial distribution was modeled through optimal semivariograms validated via cross-validation. Based on these spatial patterns, the farm was delineated into two distinct management zones using fuzzy c-means clustering. In the surface layer, Zone 1 and Zone 2 covered 49.9% and 50.1% of the Total Geographical Area (TGA), respectively. In the subsurface layer, the distribution was 51.5% (Zone 1) and 48.5% (Zone 2). This geospatial framework provides a robust foundation for site-specific nutrient management (SSNM). By identifying these zones, stakeholders can implement targeted fertilizer applications, thereby reducing input costs, safeguarding soil health, and enhancing overall crop productivity in the region.

Keywords: Soil fertility, Semivariogram, Ordinary kriging, Cross-validation, Management zones

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Comparison of Parametric and Non-Parametric Methods for Spatio-Temporal Analysis of Rainfall Trends in the West Coast River Basins of India

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Rainfall plays a crucial role in the hydrological cycle, as it has a significant influence on the climate, agriculture and water resources of the region. In this study a spatio-temporal trend analysis of rainfall from 28 rain gauge stations over 30 years' period (1986-2015) across various seasons viz. winter (JF), pre-monsoon (MAM), monsoon (JJAS), post-monsoon (OND) and annual was carried out in the west coast river basins (WCRB) of India. To assess the trends, both parametric and non-parametric tests were employed for comparative analysis. The results of the analysis revealed that out of 140 time series, trends were identified in 11(7.86%), 10 (7.14%) and 11 (7.86%) of the time series using the Mann-Kendell (MK), Linear Regression (LR) and Spearman's Rho (SR) methods, respectively, whereas Innovative Trend Analysis (ITA) detected trends in 111 (79.28%) of the time series. Additionally, ITA method identified trends in 102 (72.85%) time series that were not captured by other methods, demonstrating its effectiveness as a more advanced, intuitive and robust technique for trend detection. The mean rainfall of 30 years varied between 0.00-83.00 mm (winter), 2.37-604.31 mm (pre-monsoon), 337.28-3185.66 mm (monsoon), 26.58-717.45 mm (post-monsoon) and 788.57-3766.21 mm (annual) in the WCRB. The, rainfall variability was observed only during the monsoon season and annually. The findings have significant implications for climate resilience, water resource management and agriculture in the WCRB. The dependence of monsoon rainfall and the observed variability during the monsoon and annual time periods highlight the increasing uncertainty in the region's primary water source. Since the West Coast is highly dependent on monsoon rainfall for agriculture, even slight shifts in rainfall trends can significantly affect the socio-economic stability. Overall, this study contributes to a deeper understanding of climatological and hydrological patterns in the WCRB and their implications on agriculture and water resource management.

Keywords: Hydrology, Innovative trend analysis, Rainfall, River basin and West coast

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Soil Proximal Sensors, Remote Sensing, and AI-Driven Soil Moisture Intelligence for Climate-Smart Water Management

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Soil moisture is a critical variable governing crop growth, irrigation efficiency, and climate resilience. While satellite remote sensing provides regional-scale coverage, actionable field-level water management requires accurate, high-resolution soil moisture information derived from proximal soil sensing technologies. This lecture will present recent advances in soil moisture estimation using field-deployable proximal sensors, including Vis–NIR spectroscopy, hyperspectral imaging, thermal sensing, portable soil probes, and low-cost sensor networks, integrated with soil physical properties and agro-meteorological data. The role of AI and machine learning models in converting sensor signals into reliable soil moisture estimates and spatially continuous moisture maps will be highlighted. The talk will demonstrate how proximal sensor–based soil moisture intelligence can support precision irrigation scheduling, crop water stress monitoring, drought early warning, and water productivity optimisation at the farm scale. Case studies from diverse agro-ecosystems will illustrate scalable deployment strategies and integration with digital agro-advisory platforms.

Keywords: Soil proximal sensors, Remote sensing, AI-driven soil moisture intelligence, Climate-smart water management

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Impact of Fertilizer Doses on Growth and Grain Yield under Different Rice Cultivation Methods

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Rice (*Oryza sativa* L.) is a major food crop in India and other Asian countries. In addition to low productivity and low nutrient-use efficiency, rice cultivation faces several challenges: erratic rainfall, climate change, shrinking cultivable areas, water scarcity, and labour shortages. The SRI method has been evaluated and experimented with in 60-plus countries. Several researchers have reported yield benefits with the SRI method, along with other benefits such as seed and water savings, reduced greenhouse gas emissions, and reduced water pollution. However, little research has compared SRI with conventional transplanting systems (CTS) at different NPK fertilizer doses. Considering this, the present study aimed to understand how these two rice crop management practices and varying doses of NPK affect crop growth, yield attributes, and grain yield. A field experiment was conducted at ICAR-Indian Institute of Water Management Research Farm, Mendhasal, Odisha, during the *Rabi* season of 2024 to study the effect of different crop management practices in rice with varying NPK doses on growth, yield attributes, and grain yield. The experiment was laid out in a split-plot design with three replications, comprised of two crop establishment methods of rice, *viz.* system of rice intensification (SRI) and conventional transplanting system (CTS) in the main plot and the sub-plot treatments were T_1-0% of the recommended dose of fertilizer (RDF), T_2-25% of RDF, T_3-50% of RDF, T_4-75% of RDF, T_5-100% of RDF, T_6-125% of RDF. The recommended fertilizer dose was 80 kg N, 40 kg P_2O_5, and 40 kg K_2O ha^{-1}. The highest grain yield for both SRI (5.89 t ha^{-1}) and CTS (4.56 t ha^{-1}) was observed in T5-100% RDF. Overall, SRI produced a 30% higher grain yield than CTS. This higher grain yield under SRI was due to significant improvements in the number of panicles m^{-2} (15%), grain number per panicle (26%), grain filling % (11%), and 1000-grain weight (6%) compared with crops grown under CTS. The greater yield under SRI was due to better growth, as crops under SRI were taller, had more tillers, and had higher dry weight at different stages of crop growth. In both SRI and CTS, higher fertilizer rates led to better growth, yield, and yield attributes; moreover, the optimal fertilizer dose was 100% RDF.

Keywords: Fertilizer doses, Grain yield, Rice cultivation methods

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Groundwater Chemistry and Hydrogeochemical Processes in a Coastal Aquifer System of Puri District, India

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Groundwater is the primary source of freshwater in the coastal regions of eastern India, where aquifer systems are highly vulnerable to salinization and geochemical alterations. The present study aims to evaluate groundwater chemistry and identify the dominant hydrogeochemical processes governing groundwater quality in the coastal aquifer system of Puri District, Odisha, India. A total 48 No. of groundwater samples was collected from shallow and deep aquifers during the study period and analyzed for major physicochemical parameters, including pH, electrical conductivity, total dissolved solids, major cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) and anions (HCO_3^-, Cl^-, SO_4^{2-}, NO_3^-), following standard analytical procedures. Hydrogeochemical characterization was further supported using principal component analysis (PCA), Piper diagrams, and Gibbs diagrams. PCA identified the dominant factors controlling groundwater quality, while Piper diagrams classified groundwater into distinct hydrochemical facies. Gibbs diagrams elucidated the hydrogeochemical evolution of groundwater and the mechanisms regulating solute acquisition. The results have important implications for agricultural practices in coastal regions, as groundwater quality directly influences irrigation suitability and the potential for crop intensification. Availability of safe and suitable groundwater supports the adoption of high-yielding crop varieties, multiple cropping systems, and improved fertilizer use efficiency. Integration of groundwater quality management with crop intensification strategies can enhance agricultural productivity, sustain soil health, and reduce salinity-related risks in coastal farmlands. The study highlights the dual role of groundwater in meeting potable water demands and supporting agricultural intensification, emphasizing the need for continuous monitoring to ensure long-term sustainability.

Keywords: Principal component analysis (PCA), Hydro-geochemical evolution of aquifer, Coastal aquifer, Piper and Gibb's diagram

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Evaluating the Hydrological Effectiveness of Groundwater Recharge Structures in Nayagarh by using Sentinel 2

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Recharge structures are widely used to improve groundwater availability in semi-arid and monsoon regions. However, there is limited, clear, and reliable evidence showing how well these structures actually work at a larger spatial scale. This study proposes a remote sensing–based framework to assess the effectiveness of recharge structures implemented under the *Rashtriya Krishi Vikas Yojana* (RKVY) in Nayagarh and Khandapada blocks of Nayagarh district, located in the lower part of the Mahanadi River Basin, eastern Odisha. Multi-spectral Sentinel-2 satellite data from the European Space Agency were analysed to compare pre- and post-construction conditions around recharge structures. Changes in surface water, soil moisture, and vegetation were quantified using standard water indices (NDWI, MNDWI), a soil moisture indicator (LSWI), and vegetation indices (NDVI, EVI). Structure-wise synthesis tables were prepared to systematically summarise changes in surface water persistence, soil moisture availability, and vegetation response. These observed changes were interpreted using a process-based framework representing surface water retention, soil moisture enhancement, and groundwater–vegetation feedback, supported by before–and–after statistical analysis. Results show a clear increase in surface water extent and persistence near recharge structures, followed by sustained improvement in post-monsoon soil moisture and healthier vegetation and crop growth in surrounding agricultural areas. The coupled response of water and vegetation indices provides quantitative evidence of improved infiltration, reduced runoff losses, and enhanced groundwater-supported agriculture. This study shows that satellite-based indicators can reliably measure how well recharge structures are working. The proposed framework helps policymakers and implementing agencies assess existing recharge projects, identify the most effective structures, and apply successful designs in other areas with similar climate and hydrological conditions using easily available satellite data.

Keywords: Groundwater recharge structures, Sentinel-2 remote sensing, Water and vegetation indices, Soil moisture dynamics, Decision-support framework

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Challenges of Solar Irrigation and its spread via the PM-KUSUM Scheme in the State of Odisha

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This study examines the adoption of solar irrigation among farmers in Odisha, a state where many agricultural communities remain disconnected from the electricity grid. Most farmers in the region are small and marginal, and many interior districts still lack access to reliable electricity for irrigation, resulting in subsistence-level and limited commercial farming. However, the implementation of the PM-KUSUM (Pradhan Mantri Krishi Urja Suraksha evam Utthaan Mahabhiyan) scheme by the Government of India, in collaboration with the Odisha Lift Irrigation Corporation (OLIC) and the Odisha Renewable Energy Development Agency (OREDA), has aimed to promote solar-powered irrigation and make farmers energy-independent. The study was conducted in the districts of Sambalpur and Keonjhar, covering 160 farmers—110 adopters of solar irrigation under the government scheme and 50 non-adopters. Two blocks were selected from each district, and data were collected using a pre-tested questionnaire to assess the current status of solar irrigation, farmers' awareness of the scheme, and the challenges they face. Findings revealed significant differences in awareness levels between the districts. In Keonjhar, only 6% of farmers learned about the scheme through OREDA, while over 90% were informed via local contacts. Conversely, in Sambalpur, 73% gained awareness through OREDA, with local sources accounting for 23%. In terms of impact, 83% of adopters in Sambalpur reported an increase in cropped area due to solar irrigation. In Keonjhar, where farmers were primarily rain-fed, the introduction of solar pumps led to a 100% increase in cropped area, enabling them to grow more than one crop with assured irrigation. Despite these benefits, farmers in both districts faced similar challenges. No formal training was provided for the operation and maintenance of the solar pumps, and awareness campaigns by implementing agencies were lacking. Although OREDA provides a five-year warranty on the pumps, post-installation monitoring and support have been inadequate. The study also found a notable age difference between adopters and non-adopters, suggesting demographic factors may influence adoption.

Keywords: PM-KUSUM, Solar, OLIC, OREDA, Irrigation

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Groundwater Simulation Modeling in Coastal Odisha of India

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The groundwater simulation modeling study was taken up in the *Puri* central canal system's *Phulnakhara* distributary command, which is part of the boundary of *Cuttack* and *Khurda* districts, located in the coastal areas of eastern India in the state of Odisha. The study in the command was taken up during 2021 and 2022, located between $20^0 19' 15.6''$ N to $20^0 14' 56.4''$ N latitude and 85^0 52′ 51.6′′ E to 86^0 0′ 0′′ E longitude. The flow modeling of the *Phulnakhara* distributary command (49.03 km^2 area) was done by Visual MODFLOW (VMOD). The command area's conceptual model was created by assigning various input data, and the developed model was calibrated with 1 year data (2021) and validated with 1 year data (2022) on a fortnightly basis for simulating the groundwater flow. Both steady and transient state circumstances were used to calibrate the hydraulic conductivity and storage coefficient for the various layers for 2021. The calibrated hydraulic conductivity and specific storage values vary from 1.16 $x10^{-3}$ ms^{-1} to 4.86 x 10^{-4} ms^{-1} and 2.00 x 10^{-2} m^{-1} to 4.00 x 10^{-6} m^{-1}, respectively for the multi aquifer in both state scenarios indicating safe for 10 years from the point of current groundwater development. The modeling study revealed that, the coefficient of determination (R^2) and Nash-Sutcliffe Efficiency (NSE) during validation varied from 0.65 to 0.90 and 0.62 to 0.88, respectively in the command area showing that there is a close agreement between the VMOD estimation and actual value observed in the command for the best predictive simulations.

Keywords: Conjunctive use, Calibration, Simulation models, Validation, VMOD

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Development of a Cloud-Based Geospatial Crop Model for Large-Area Crop Growth and Yield Simulation

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Accurate and timely assessment of crop growth and yield over large spatial extents is critical for operational agricultural monitoring, production forecasting, and decision support. Conventional process-based crop models, while robust at plot scale, face limitations in scalability, real-time data integration, and computational efficiency when applied at regional to national scales. To address these challenges, a cloud-based geospatial crop modelling framework was developed under the FASAL 2.0 programme using the Google Earth Engine (GEE) platform. The developed geospatial crop model integrates satellite-derived biophysical variables with crop growth principles to simulate crop phenology, leaf area index (LAI), total dry matter accumulation, biomass partitioning, and final yield at high spatial and temporal resolution. Time-series multispectral satellite data are used to dynamically derive LAI and phenological stages, which drive radiation interception and biomass production modules. Assimilated weather inputs and crop-specific parameters enable simulation of total dry matter production and its partitioning into economic yield components. The cloud-native implementation on GEE allows seamless handling of large datasets, near-real-time processing, and scalable model execution across millions of agricultural fields. The proposed framework demonstrates the feasibility of translating classical crop growth concepts into an operational geospatial modelling system, enabling spatially explicit crop condition monitoring and yield estimation. The cloud-based geospatial crop model offers a robust pathway for large-area crop forecasting, climate impact assessment, and policy-relevant agricultural intelligence, supporting national-scale operational programmes such as FASAL and digital agriculture initiatives.

Keywords: Cloud-based geospatial crop model, Yield simulation

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Soil Micronutrient Status as Influenced by Nutrient Management Practices under Rainfed Drought Prone Ecology

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Most of the crop-land areas in Jharkhand come under rainfed drought prone ecology. In the *kharif* season farmers mainly grow rice and in *rabi* most of the lands are kept fellow due to lack of sufficient moisture. Continuous practice of mono-cropping or rice-fallow led to decline in soil fertility and quality which directly reflected in low productivity. Pigeon-pea is an important alternative crop for this region during k*harif* and adds a considerable amount of plant biomass through roots, leaf fall, root exudates etc. and also soil nitrogen, being a legumes crop. In uplands, rice is grown as direct seeded crop (direct seeded rice; DSR) due to shortage of water and irregular rainfall. Average productivity is low due to several biotic and abiotic factors. In direct seeding (upland condition) availability of several nutrients, major as well micro-nutrients is a concern. Hence selection of proper nutrient management and cropping system may be useful to enhance the system productivity as well as soil fertility and quality. To evaluate the nutrient management options on soil micronutrient content, soil samples were collected from a four year old field experiment having different nutrient management practices (inorganic, organic and integrated) under sole rice (Sahbhaghidhan) and rice- pigeon pea (Birsa Arhar-1) intercropping. Integrated nutrient management (INM) comprising of 50% RDF along with FYM @5 t ha^{-1} and (VAM 1.5 q ha^{-1} with PSB 4 kg ha^{-1}) recorded highest micronutrient (Fe, Cu, Mn and Zn) content (21.68, 1.19, 13.87 and 0.63 ppm respectively) under rice and (21.74, 1.23, 12.40 and 0.53 ppm respectively) under rice pigeon pea intercropping. This INM practice is found better in maintaining the micronutrient status under rice as well as rice pigeon pea intercropping as compared with the other inorganic and organic nutrient combinations.

Keywords: Soil micronutrient, Nutrient management practices, Rainfed drought prone ecology

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Elucidating the Direct and Indirect Effects of Elevated Atmospheric CO_2 and Submergence Stress on Rice Productivity Using Structural Equation Modelling

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Understanding how elevated atmospheric CO_2 and submergence stress affect grain yield and morpho-physiological traits is crucial for advancing rice research. To address this, we conducted a field experiment to examine morpho-physiological responses in submergence-tolerant and susceptible rice varieties exposed to elevated CO_2 and submergence. The experiment involved two CO_2 regimes [ambient, 400 ± 10 μmol mol^{-1}; elevated, 550 ± 20 μmol mol^{-1}] and four Indica rice (*Oryza sativa* L.) cultivars: Swarna-Sub1 and IR64-Sub1 (submergence-tolerant) along with their recurrent parents Swarna and IR64 (submergence-susceptible). Path analysis using Partial Least Squares Path Modeling (PLS-PM) was employed to distinguish direct and indirect drivers of grain yield under these combined stresses. The model incorporated 11 variables grouped into five latent constructs: (1) antioxidant metabolites (e.g., catalase, peroxidase), (2) non-structural carbohydrates (e.g., starch, sugar), (3) chlorophyll (chlorophyll a & b), (4) yield attributes (fertile grains per spikelet, panicle length, panicle weight), and (5) plant survival traits (shoot elongation, plant survival).

Results highlighted antioxidant metabolites as the strongest determinant of grain yield, with the highest path coefficient (β = 0.988). Non-structural carbohydrates (β = 0.231), yield attributes (β = 0.236), and chlorophyll (β = 0.445) also contributed significantly. Both antioxidant metabolites and non-structural carbohydrates exerted direct effects on grain yield, with their influence more pronounced under elevated CO_2 than ambient conditions. The PLS-PM model showed no multicollinearity issues and achieved high R^2 values, confirming robustness. These findings provide critical insights for breeding programs aiming to develop rice cultivars resilient to combined environmental stresses, particularly in the face of climate change.

Keywords: Elevated [CO_2], Submergence, Floodwater, PLS-PM

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Soilless Cultivation: An Innovative Approach to Boosting Dragon Fruit Quality and Yield

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Soilless cultivation has gained recognition as an innovative agricultural approach capable of enhancing crop yield and quality while overcoming the constraints of traditional soil-based farming. In dragon fruit (*Hylocereus* spp.) production, soilless systems offer considerable scope for improving productivity, fruit quality, and resource-use efficiency. A study was conducted at ICAR–Indian Institute of water Management, Bhubaneswar, during 2021–2025 to evaluate aggregate hydroponic-based dragon fruit cultivation under open-field conditions.To accomplish the above-mentioned task two varieties of dragon fruit (pink pulp type & white pulp type) were planted in HDPE pot (height: 448mm, dia: 590mm, weight: 4.7 kg) with four different growing media (Cocopeat, Coco fibre, Cocopeat+ perlite & soil) in four planting systems (1 plant/pit, 2 plants/pit, 3 plants/pit and 4 plants/pit) in CRD design with three replications under open field condition.Among the treatments, cocopeat and its combinations, particularly cocopeat + perlite, significantly improved root-zone aeration while substantially reducing water consumption (168 L compared to 624 L under soil cultivation). The cocopeat + perlite medium recorded superior fruit quality parameters, including higher peel weight (121 g vs. 41 g), pulp weight (283 g vs. 111 g), and total soluble solids (17.4 °Brix vs. 16.85 °Brix) compared to soil. Average fruit weight was markedly higher in cocopeat (404 g) and cocofiber (368 g) compared with soil-grown plants (152 g). Cocopeat+ perlite gave the highest yield (30.4 kg/pot), followed by cocopeat (21.6 kg/pot), cocofiber (14 kg/pot), and soil (12.5 kg/pot), confirming the superior performance of the soilless-based treatments. Severe pruning (80% removal) increased the fruitful cladode (39.5% over 20.31%), moderate pruning (60% removal) increased the fruit set (87.42% over 68.20%), light pruning increased new sprouts (23 nos over 8 nos). Severe pruning driven reproductive development, while moderate pruning achieved a harmonious balance between vegetative regrowth and reproductive output. Light pruning provided gradual structural improvements. Overall, soilless cultivation systems facilitate year-round production and efficient land utilization, making them especially suitable for urban agriculture, protected cultivation, and resource-constrained environments. Adoption of this technology can enhance grower profitability while meeting the increasing global demand for premium-quality dragon fruit.

Keywords: Soilless cultivation, Fruit quality, Yield

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Rainfall-Driven Meteorological Drought Monitoring in Odisha Using MDM Software

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Drought is a complex natural hazard with far-reaching socio-economic and environmental consequences, posing a significant threat to agricultural productivity, water resources, and ecological stability. Effective monitoring and management of drought are therefore crucial for minimizing its impacts and enhancing resilience. This study utilized long-term daily rainfall data (1990–2021) at a spatial resolution of 0.25° × 0.25°, obtained from the India Meteorological Department (IMD), to examine rainfall trends across drought-prone districts of Odisha, namely Nuapada, Balangir, Bargarh, Kalahandi, and Kandhamal. Rainfall trends were analyzed using the Mann–Kendall test and Sen's slope estimator, while meteorological drought conditions were assessed using the Meteorological Drought Monitor (MDM) software was used to monitor and analyse drought using a variety of meteorological drought indices Standardized precipitation Index (SPI), Percent Normal Index (PN), Deciles Index (DI), Rainfall Anomaly Index (RAI), Z-score Index (ZSI)and China Z- Index (CZI). Results revealed that all districts showed decreasing non-significant rainfall trends except Nuapada district (non-significant increasing trend). The significant drought years identified using MDM software were 1996, 1997, 1998, 1999, 2000, 2002, 2005, 2010, 2011, 2016, 2017, 2019 and 2021; 1996, 1999 and 2002emerging as the most intense drought episodes. Moderate drought events occurred more frequently than severe and extreme events across the study region.Pearson's correlation coefficient was used to compare the indices; SPI and PN values had the highest correlation, with a R^2 value of 0.99. The R^2 value for south-west monsoon ranged between 0.98 to 0.99 for SPI and CZI. High correlation among drought indices confirms the robustness of SPI-based monitoring for effective drought assessment and resilience planning. Overall, the findings highlight the robustness and applicability of the Meteorological Drought Monitor (MDM) as an effective tool for drought monitoring and assessment across diverse regions, contributing to informed decision-making and sustainable environmental management.This study supports informed decision-making for water resource management, agricultural planning, and climate resilience strategies under changing rainfall patterns.

Keywords: Drought monitoring, MDM software, Rainfall trend, Mann–Kendall test, Precipitation indices

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Mitigating Chromium Toxicity and Improving Rice Yield in Chromium-mined Regions of Odisha

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In the twenty-first century, heavy metal pollution has grown to be a major worldwide issue that impacts both human health and environmental safety. India is the third-largest producer of chromite ore in the world, and about 98% of India's chromite ore reserves are found in the Sukinda Valley of Jajpur district, Odisha, and rice is the major crop of that region. Rice cultivation in Cr polluted soil led to increased accumulation of Cr in grain and significantly reduced rice yield. So, in this research work, efforts were made to find out suitable management strategy for ameliorating Cr toxicity in rice. A pot experiment was conducted for two years (2023-2024) at a net house in a factorial complete randomized design. The treatments comprised two levels of Cr stress, four management techniques and two methods of irrigation practice. The elevated level of Cr stress (20 mg Cr kg^{-1} soil) significantly reduced the height and chlorophyll content of rice plant at flowering, and increased the chaffy grain percent which ultimately reduced the grain yield of rice as compared to the plant grown under natural level of Cr stress. As compared to control (without amendment), application of vermicompost, seed priming and their combined use improved the growth and chlorophyll content of rice plant. The combined application of vermicompost followed by seed priming with Fe significantly enhanced the chlorophyll content by 31% and reduced the chaffy grain by 65.5% and ultimately enhanced the grain yield by 58.3% over control. This treatment combination also diminished the Cr uptake and its subsequent translocation to the plant parts. The combined application of vermicompost and seed priming technique outperporfed their sole application in enhancing growth and yield of rice plant and also restricting the uptake and translocation of Cr by rice plant.

Keywords: Chromium toxicity, Rice, Yield, Odisha

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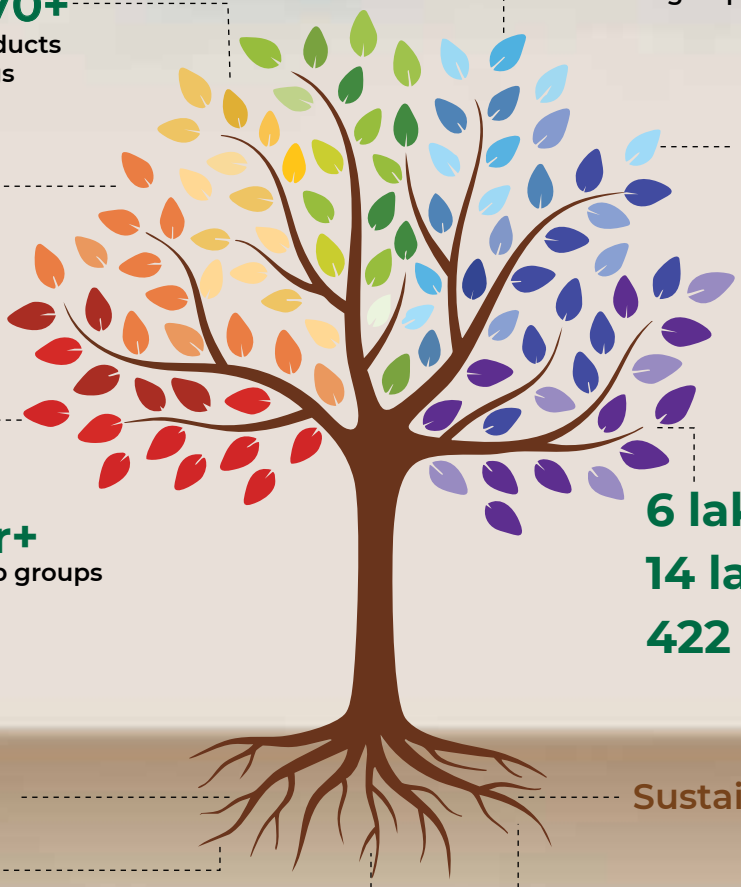

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