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Development of Center Pivot Irrigation Systems to Revolutionized Modern Agriculture Irrigation

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Abstract- A well-designed main line is the backbone of any center pivot irrigation system. Ensuring it's optimally sized and configured helps in achieving uniform water distribution, preventing pressure variations that could affect sprinkler performance. By using analytical methods such as hydraulic modeling, and optimization techniques, one can fine-tune pipe sizes, pump capacities, and valve configurations to ensure maximum efficiency. As you mentioned, AI-driven modeling could play a crucial role in real-time monitoring, helping predict system behavior under varying conditions. With real-time data, adjustments could be made on-the-fly to optimize water usage and reduce waste, even accounting for changing weather patterns or soil moisture levels.

Index Terms-well-designed main line, pivot irrigation system, preventing pressure variations, AI-driven modeling, optimize water usage

I. INTRODUCTION

Centre pivot irrigation systems are widely used for efficient water distribution in large agricultural fields. The main line, which delivers water from the pump to the pivot, plays a crucial role in system performance. This study presents an analytical approach and optimization techniques for designing the main line, considering hydraulic efficiency, energy consumption, and cost-effectiveness. Pivot irrigation in particular, ensuring optimal water use and maximizing agricultural productivity. This involves precise control over water application, integrating advanced technologies such as soil moisture sensors, variable rate irrigation (VRI), and remote monitoring systems. In Egypt, the adoption of center pivot irrigation has significantly contributed to the expansion of agriculture in desert areas, allowing for the cultivation of crops in previously arid regions. However, challenges remain, including the high initial investment cost, the need for reliable water sources, and the potential for over-irrigation if not managed properly. To enhance the effectiveness of center pivot irrigation, research efforts focus on improving system design, optimizing energy use, and incorporating sustainable water management practices. The integration of renewable energy sources, such as solar-powered pumps, further increases the feasibility of using center pivot irrigation in remote areas. The development of center pivot irrigation systems revolutionized modern agriculture, particularly in regions with limited rainfall but significant underground water resources. Property near More has been part of a comprehensive study comparing different irrigation systems over the past decade, particularly for cotton irrigation. The inclusion of siphon, bank less channel, lateral move, and subsurface drip irrigation systems allows for a broad view of how various methods perform under different crops and water use conditions.

The focus on both yield and gross production water use gives important insights into water efficiency and overall productivity for each system. Would you like to explore how these systems compare in terms of water conservation or crop yields.

Two common types of irrigation systems:
Surface Irrigation: This involves applying water directly to the soil surface. It can be done through various methods, such as siphons or small pipes through banks in a bank less channel, or even using bay irrigation systems. Water flows across the soil, relying on gravity to distribute it evenly. This method is widely used for crops like rice, but it can also be adapted to different agricultural settings.

Overhead Irrigation: In this system, water is applied above the crops, typically using systems like lateral move or center pivot irrigation. These systems have rotating sprinkler arms that distribute water in a controlled manner, ensuring even coverage. Overhead irrigation is often used in fields with more uniform terrain, such as row crops or orchards.

II. LITERATURE REVIEW

Muller et al. (2020) developed a new methodology using mathematical optimization techniques. In the design and operation of water delivery systems that offer the potential to improve energy efficiency while also lowering investment costs significantly. It provided a systematic methodology utilizing mixed-integer nonlinear and mixed-integer linear modelling approaches for optimal design and operation of pumping systems in actual high-rise structures. It also takes into account different booster station topologies such as central booster stations that are decentralized, parallel and series parallel. In order to confirm the accuracy of the underlying optimization models with actual system behavior present validation results based on tests utilizing a modularly constructed pumping test rig. It can be used the models to incorporate layout and control decisions for various load scenarios producing a deterministic analogue of a two-stage stochastic optimization process. By piecewise linearizing and relaxing the properties of the pumps, it generated mixed-integer linear models. In order to save calculation time, it can provide a problem-specific precise solutions method in addition to the commercial solver-based solution. In order to efficiently explore the solution space, it divided the issue into smaller sub problems that can be partially cut off throughout the solution process. The effectiveness and suitability of the proposed solutions for actual structures were also examined. Engineers assessed the technical aspects of the solutions while keeping in mind the critical economic trade-off between capital expenditures and operational expenses.

Alsayim (2021) discussed that the research was carried out on the eastern bank of the Atbara River during the winter of 2019–2020 under desert-high terrace soil. The increasing usage of modern irrigation systems, particularly center pivot irrigation systems necessitate understanding how effectively they can be used. Thus, defining the characteristics of water distribution under these systems. The four center pivot sprinkler irrigation systems make up the trial units. Warm winters and a semi-arid environment were the norms. Penman-Montecito results for evapotranspiration varied from 5.69 to 6.26 mm/day for November and December and from 6.14 to 6.89 mm/day for alfalfa crop (Medic ago sativa) consumptive usage, respectively. The results revealed that diverse management practices impacted the hydraulic performance of uniformity coefficients C.U., distribution uniformity D.U. and potential efficiency of low quarter PELQ for the center pivot systems. This indicated a lack of adherence to the design requirements for sprinkler placement and distribution an undesirable irrigation schedule.

III. METHODOLOGY

Discusses several critical factors and guidelines for the land application of wastewaters using sprinkle systems. To summarize the major concerns:

Wastewater Quality: The wastewater must be of good quality to avoid harming the environment. Contaminants such as oils, greases, and heavy metals can damage soil and vegetation.

Soil and Vegetative Considerations: The effluent must be applied in a manner that doesn’t destroy or affect the vegetative cover, and excessive solids should be avoided to prevent mat formation on the soil surface.

Soil Type: Well-drained, deep sandy or loamy soils are ideal for wastewater application. Some soils may require subsurface drainage to handle the effluent.

Application Rate: The application rate should align with the soil’s infiltration rate, usually not exceeding 0.25 inches per hour (iph). The total application per week can vary, but 1 to 4 inches is typical, with higher application rates during summer months.

Rest Period Between Applications: To prevent negative environmental impacts, there should be a rest period between applications.

Disposal Sites: Woodlands can be effective disposal sites for wastewater because the soil surface remains stable, and the vegetation aids in digesting organic matter. For grasslands, special care is needed to ensure the vegetation and soil can handle the wastewater effectively.

In designing a system, it's crucial to balance these factors to avoid groundwater contamination and soil degradation. The goal is to ensure the sustainable and environmentally safe disposal of wastewater while protecting the land's health.

IV. RESULT AND ANALYSIS

Exploring different systems and their impact on yield across various seasons. The data shows that system selection and seasonal optimization are both important factors in maximizing productivity. The 1.16 bales/ha difference between systems and the 3.4 bales/ha difference between seasons suggest that adjusting practices based on seasonal conditions can lead to more efficient results. The key takeaway from the research is that the ideal irrigation system depends on a farm's specific conditions, particularly water reliability and labor availability.

Surface irrigation systems like siphon or backless channels often have lower initial setup costs, but backless channels may require more earthworks.

For farms with low water reliability, systems with lower capital costs (such as traditional siphons) are common, although these can result in higher ongoing labor costs.

Farms facing labor shortages may opt for backless channels or siphon-less systems, or invest in automated siphon systems to address labor challenges.

For farms with high water reliability, the initial investment in systems like overhead or drip irrigation is more feasible because the costs can be spread over many productive seasons.

There has been significant progress in investigating siphon-less or backless irrigation systems, particularly in terms of water use efficiency. The collaboration between organizations like GVIA, CRDC, NSW DPI, and along with the development of the siphon-less booklet and field day, is a great step in sharing knowledge and experiences among producers.

The Smart Irrigation project led by Dakin University, utilizing wireless sensor networks, sounds promising for enhancing irrigation management. By linking sensors with forecasting systems and automated irrigation infrastructure, it will allow for more precise water delivery, which is crucial for improving water use efficiency in agriculture, especially in systems like backless channels that are typically used for flood irrigation.

The integration of technology to monitor and control water usage could potentially lead to better crop productivity while minimizing water waste, a key consideration in areas facing water scarcity or those seeking more sustainable farming practices. How do you think this approach will impact other agricultural regions.

V. CONCLUSION

This passage highlights the critical steps in ensuring the success of a sprinkler irrigation system designed for conservation and maximum crop yields. It underscores that having a well-prepared plan is only part of the equation. The actual effectiveness of the system heavily relies on purchasing the right equipment, proper installation, and ensuring it is operated correctly.

The plan should include a clear map of the design area, showing essential components like water supply, pumping plant, supply lines, and sprinkler spacing. Minimum equipment specifications are also emphasized, particularly the performance details of the sprinklers and pump. The importance of uniformity in water distribution and energy efficiency are key goals.

The passage also addresses the potential issue where farmers may purchase equipment that differs from the specified plan, which could affect the system's performance. While it's not the responsibility of the engineers to control equipment purchases, it's crucial for farmers to understand the significance of selecting a system that meets the necessary specifications for energy conservation and optimal crop watering.

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