Food and Agriculture Organization of the United Nations

Promoting productive water use and efficient water management in paddy fields

Farming practices for enhanced water management in paddy fields in Zambia

THE PROJECT

In view of the projected global water demand, improved water use efficiency in irrigation is crucial to sustainably increase agricultural productivity. Paddy field systems are particularly water demanding, though products such as rice are not only a staple food but also constitute a major social and economic activity that provides public goods, as well as employment and income, to the rural population.

Funded by the Government of Japan, the project "Promoting productive water use and efficient water management in paddy fields" is implemented by the Land and Water Division of the Food and Agriculture Organization of the United Nations (FAO) in collaboration with partners and national institutions in Sri Lanka and Zambia. The project primarily consists of establishing pilot sites to demonstrate enhanced water management and building the capacities of stakeholders on the multifunctional and value-added paddy fields in the two countries.

The pilot sites are equipped with flow-measuring devices to monitor and collect data on paddy water management and to compare the performance of conventional and improved water management measures in paddy fields.

Output 1 of the project "Technical assessment of water management and demonstration of enhanced water management in paddy fields at pilot sites" aims to find evidence-based results on the benefits of enhanced water management through:

selecting pilot demonstration sites and setting up water measuring equipment;

monitoring and collecting data at the pilot sites; and

implementing full pilot demonstration sites.

In Zambia, the project was implemented in collaboration with the Zambia Agriculture Research Institute (ZARI), under the Ministry of Agriculture of Zambia. ZARI has been spearheading rice research in collaboration with the Japan International Cooperation Agency (JICA) to support the national objective of enhancing food security by diversifying crop production away from maize cultivation. Rice is increasingly recognized as a strategic crop to fulfil this objective. To streamline efforts, the project drew on the achievements of ongoing programmes and initiatives.

COUNTRY PROFILE

Rice has become the third most important cereal crop after maize and wheat. It is also an important cash crop in the Zambian economy and has recently been included in the national food balance sheet. At the producer level, rice is a major source of income in three regions: the Chambeshi floodplain in Luapula and Northern provinces; the Upper Luangwa valley and Chama district in the Muchinga province; and the Zambezi floodplain in the Western province. There are also small pockets of land with high potential for rice production, but farmers in these areas generally grow a small amount of traditional, aromatic and low-yielding rice varieties for their own consumption.

The production volume has been steadily increasing, with 65 880 tonnes produced in 2021. However, the yield productivity is low at an average of 1.42 tonnes/ha. Such figures are relatively low compared to other eastern and southern African countries, whose average yields reach 2.5 tonnes/ha.

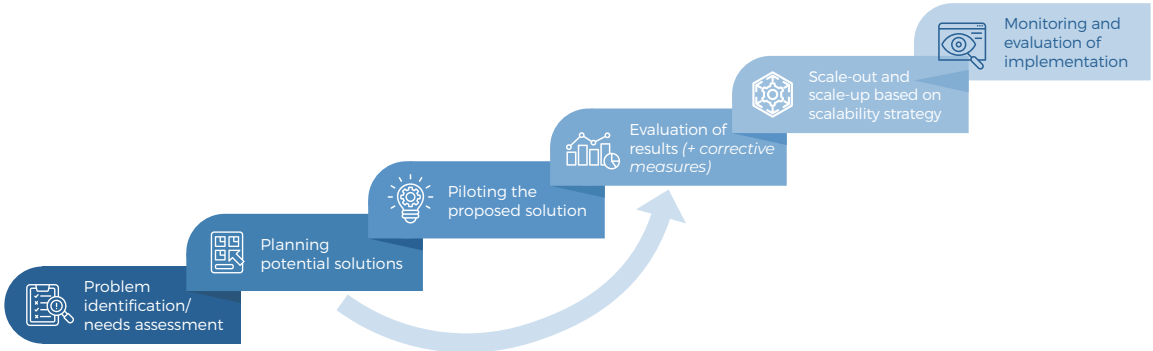
THE APPROACH FOR DEVELOPING BEST PRACTICES FOR ENHANCED WATER MANAGEMENT

The project applies FAO's knowledge management cycle to ensure that the recommendations are robust, effective, sustainable and ready to use without entailing social or environmental risks.

Problem identification

Rice growers continuously face low rice yields, despite significant achievements in the sector's development. Factors contributing to low yields include poor access to quality seeds, lack of established practices in emerging regions, minimal levels of mechanization, and dependence on unpredictable rainfall. Together, these lead to compromised yield volume and quality at

FIGURE 1. The project knowledge management cycle

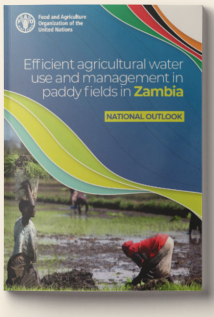


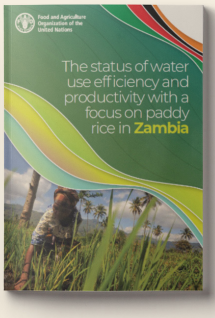
Source: Authors' own elaboration

the national level in Zambia. Furthermore, the rice sector's development requires strategic enhancement in both the upstream and downstream markets as their accessibility is limited.

Phase 1 of the project "Efficient agricultural water use and management enhancement in paddy fields" was implemented to increase the understanding of the status of water use efficiency and water productivity, identifying both limits and potential at the national level. The analysis provided a foundation for technical and policy support to stakeholders in the target countries to enhance water resource management in paddy fields. Strategies and investment portfolios were developed to ensure the scaling-up and replication of the results. Phase 1 collected and analysed data and information on water resources and irrigation systems, and identified both technical and policy measures to sustainably improve water resources management and crop productivity with a focus on paddy fields. The analyses in Phase 1 completed the problem identification and needs assessment step of the knowledge management cycle at the national level.

At the community level, field assessments and consultations were conducted to identify the acute conditions that affect crop yields or may ultimately prevent farmers from continuing rice production. Farmers face various challenges throughout the production chain. One of the key challenges is the efficient use of inputs, particularly in land preparation and fertilizer management, which can significantly affect production volume. Additionally, the adoption of inadequate post-harvest technologies may compromise the quality of the final products. Therefore, projects and programmes that aim to improve water use efficiency and productivity should integrate measures throughout the entire production cycle, rather than solely emphasizing optimal irrigation practices. This issue is further complicated by the specific geographical distribution of paddy fields. As pocket areas expand across the country, covering various agroclimatic, environmental and





socioeconomic conditions, interventions must be tailored to the specific characteristics of these areas. In this context, bottom–up approaches are preferred over generic solutions.

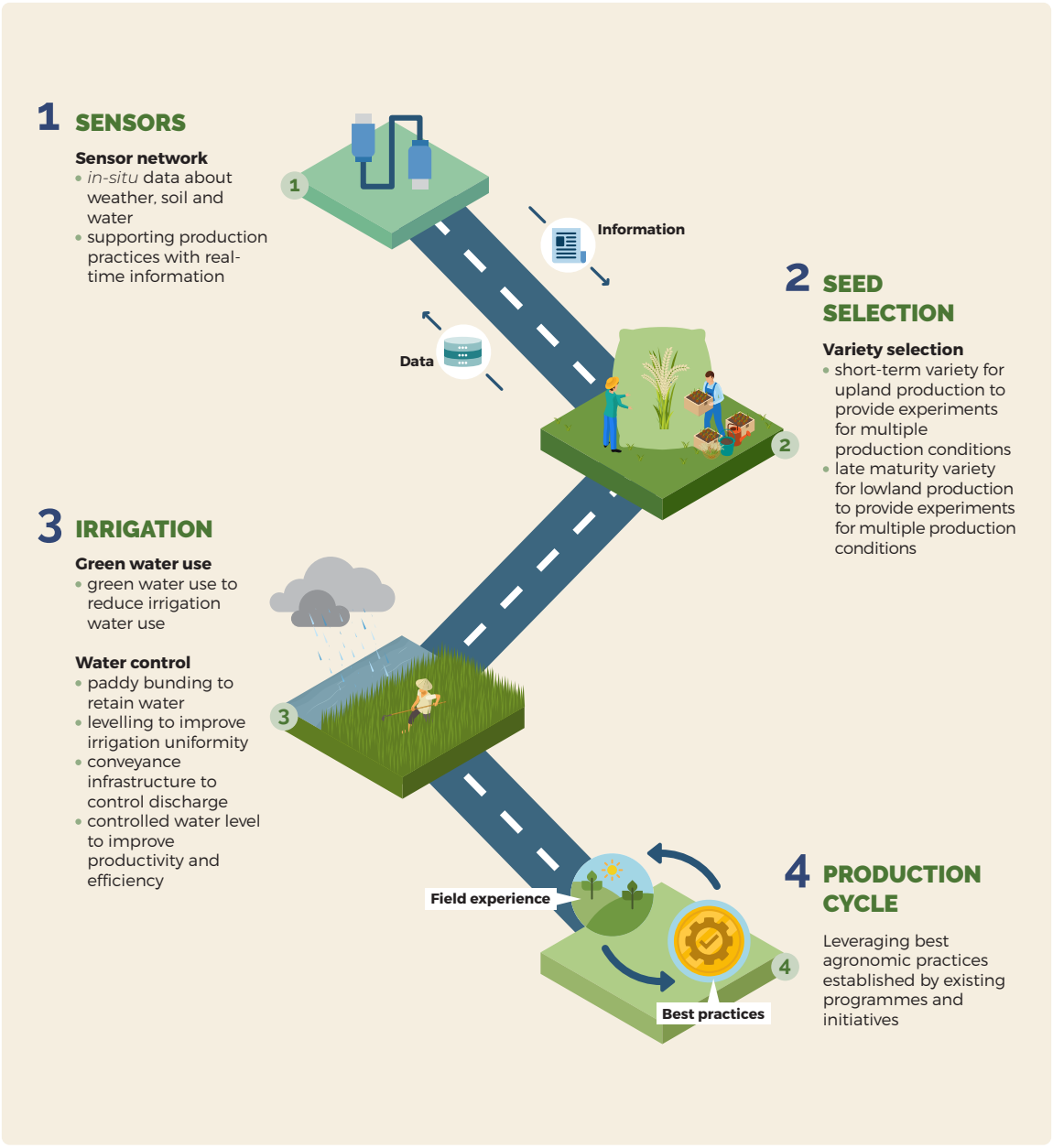
Planning and piloting

The project built on existing initiatives that support paddy rice research in Zambia. It was designed to complement the recommended agronomic practices with effective water management strategies, which have been neglected in current initiatives. The pilot involved control and treatment fields in a research environment. The objective of the pilot was to provide evidence of potential yields under optimal water conditions combined with recommended agronomic practices. Field visits and community consultations were conducted to document production practices and performance levels, establishing a baseline for rice production. The baseline is valid only in the case of communities, where rice production is still in its infancy, and no research or development project has been deployed to support the establishment of adequate practices. Evaluating input use efficiency and productivity is crucial in these conditions, as it accurately reflects the readiness of farming communities to adopt rice production practices. Thus, it indicates how the sustainable expansion of rice production can be planned. The comparative analysis of the control and treatment plots, along with the field conditions, provides a comprehensive

overview of both actual and potential production levels. The implemented agronomic and irrigation practices were centred around the following production phases and inputs:

- variety selection, including upland and lowland varieties;
- land preparation and planting methods, including nursery bed;
- weeding and fertilizers;
- water management; and
- harvest and post-harvesting techniques.

FIGURE 2. **A suite of productivity and efficiency measures introduced in the pilot fields**



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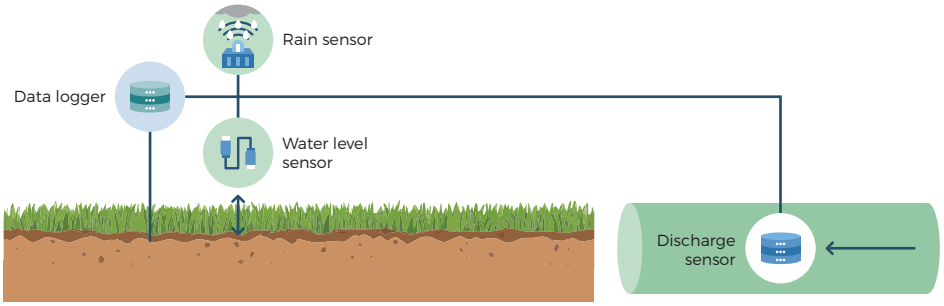
The foundation of the pilot design was the equipment of the field with proper water infrastructure, which was essential for simulating irrigation management scenarios. Many rice-producing regions lack adequate irrigation systems, making it important to demonstrate an optimal design through the pilot project. This design incorporated several key components of the irrigation system, including storage facilities, conveyance infrastructure, control equipment and monitoring devices. It is easily scalable and can be replicated by community-based management programmes. The pilot project also showcased designs for on-farm water management. Practices like land leveling and creating paddy bunds are not commonly used in Zambia, yet they are crucial for retaining and efficiently using both rainwater and irrigation water.

The project installed a water monitoring system to evaluate the water requirements for paddy rice cultivation. In Zambia, rice farmers rely heavily on rainfall, as the rice-growing season coincides with the wet season, enabling them to maximize the use of available green water. To assess both rainwater use and irrigation water use, a monitoring system was designed to acquire data on the amount of rainwater, discharge, and water level in the paddies. An automated rain gauge and pressure sensors were assembled and connected to a datalogger. The datalogger collects the relevant data every 30 minutes and transfers it to a cloud-based platform.

FIGURE 3. Stylized figure of the monitoring system components



Source: Authors' own elaboration

Evaluation of results

The evaluation of field conditions reveals that production performance fluctuates from year to year, depending on the weather. Although freshwater resources are available and accessible in many rice-producing regions, farmers often rely solely on rainfall. This makes them vulnerable to severe climate events, such as dry spells and drought. In extremely dry years, productivity can be halved, resulting in yields of less than 1 tonne/ha.

Both upland (NERICA4) and lowland varieties (Supa MG and Kilombero) were piloted to assess the rice production potential in different environments. The pilot proved that optimal agronomic and irrigation practices can double the yields that farmers produce in rainy years (Figure 3).

The control and treatment fields were cultivated with the same agronomic practices but with distinct water management practices. The control plot received the full amount of water, without adjusting the supply to the crop demand. Irrigation water supply reached up to 25 000 m^3/ha in the case of two varieties, while the treatment plot required over 30 percent less water (Figure 5).

FIGURE 4. Comparison of yield levels between field conditions and the pilot

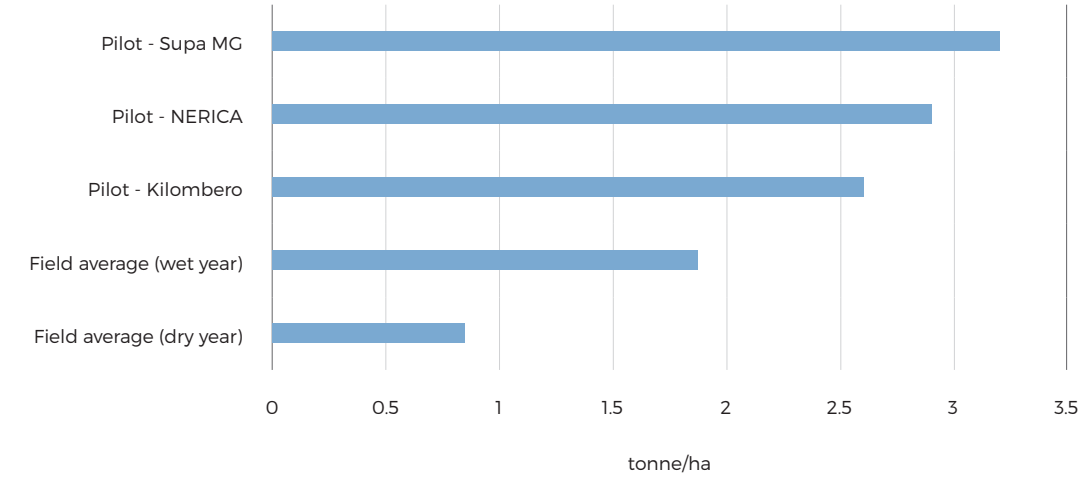


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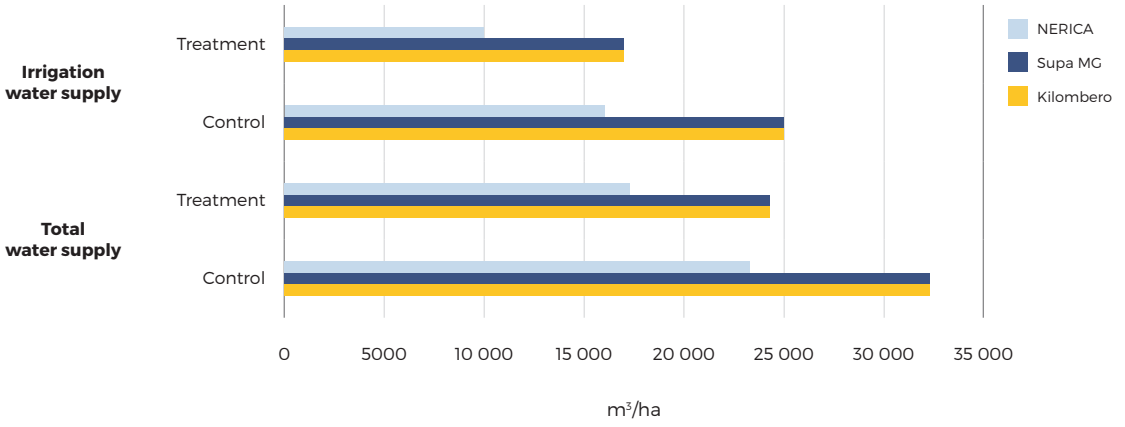
FIGURE 5. Comparison of the total water supply and irrigation water supply between the treatment and control plots



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To demonstrate the benefits of effective water management practices, the biomass and yield productivity of control and treatment plots were compared. The results showed that grain productivity increased by 13–44 percent, while biomass productivity rose by 7–11 percent due to proper irrigation management.

Due to the increased yield with decreased irrigation supply, the crop water productivity increased from 0.14 to 0.3 kg/m^3 in the case of NERICA, from 0.12 to 0.19 kg/m^3 in the case of Supa MG, and from 0.07 to 0.16 kg/m^3 in the case of Kilombero. This translates into an average 100-percent increase in crop water productivity.

FIGURE 6. Comparison of the productivity values of three varieties between the control and treatment plots

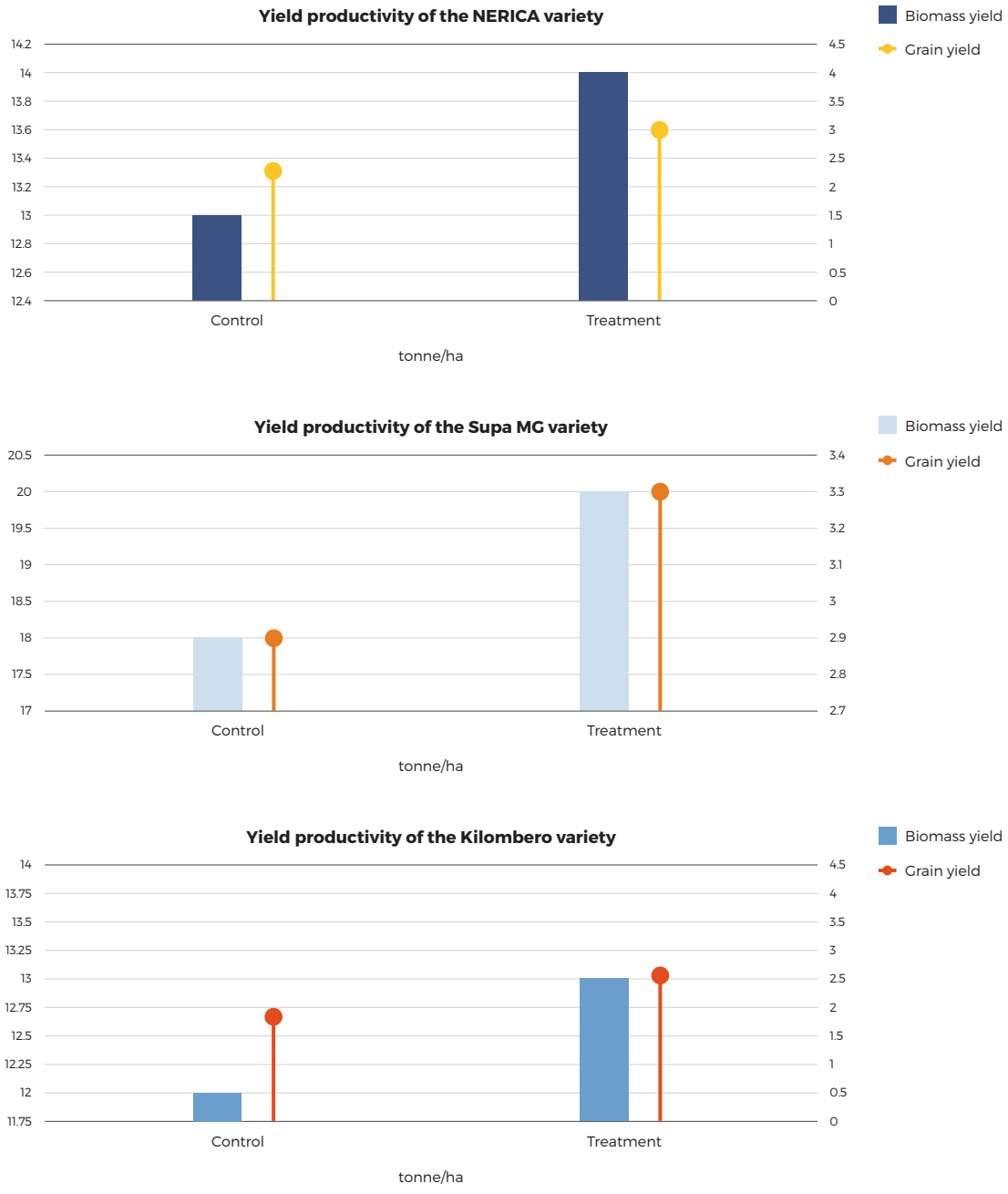

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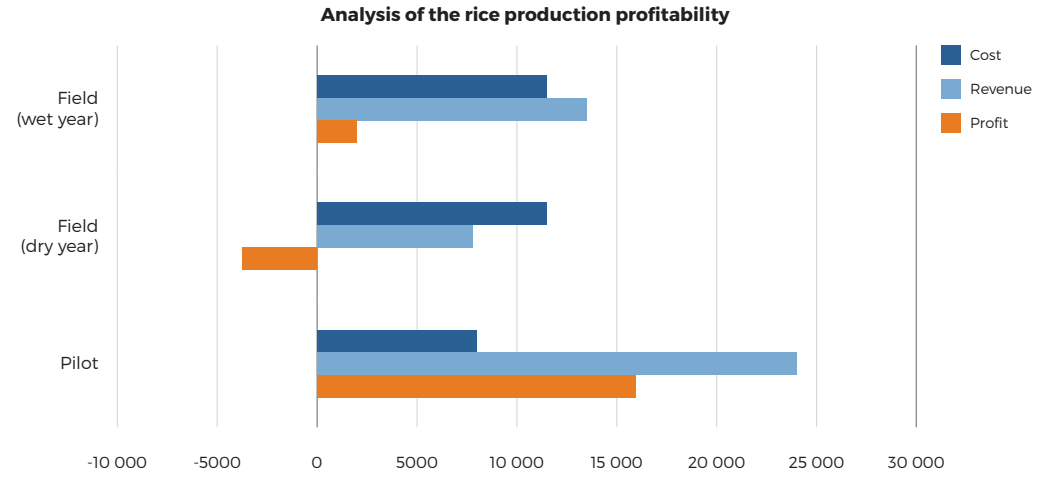
FIGURE 7. **Comparison of the profitability levels of different production environments**



Source: Authors' own elaboration

Rice production is more resource-intensive than traditional crops like sorghum and maize, leading to a different production cost structure. Low yields can threaten farm profitability, potentially resulting in negative profits in extreme cases, such as dry years. Even the average yield levels are just enough to provide a decent income. Since rice is regarded as a cash crop in Zambia, demonstrating its profitability is crucial to encourage farmers to transition to rice production. The increased revenue demonstrated by the pilot is due to two factors: 1) Optimized resource use can decrease the total production cost, and 2) Zambia has a negative rice trade balance, which means that the domestic market can absorb rice if the quality and volume requirements are met. Consequently, the yield productivity increases revenue.

Scalability strategy

The scalability strategy is based on the concept of community-driven development, given the spatial pattern of rice-producing areas and the structure of rice sector development. This basis can accelerate the scale-out phase and provide an opportunity to communities that are just entering the rice sector. The project involved the following strategies to foster community-driven development of rice production:

Mapping of potential: The potential for rice production in Zambia has already been identified, but its strategic implementation requires accelerators. Linking the stakeholders along the production cycle is a necessary step to enable the sustainable expansion of paddy rice production. This applies to horizontal and vertical stakeholders, putting the communities at the centre of the process.

Demonstration and awareness: Due to the lack of established practices, demonstrating research and development results to farmers can raise the interest of smallholders and eventually engage them in rice production. Equipping and making demonstration farms accessible can guide the entire production cycle across different environments, thereby converting existing theory into field practices. Such demonstration facilities can contribute to the peer learning process within and outside the communities.

The key entry points for the scalability of the approach and measures are the following:

FIGURE 8. **Scalability strategy for rice production**

Source: Authors' own elaboration

Monitoring and evaluation of the implementation

Along with the pilot design, the project established a monitoring protocol to track key performance indicators related to water management, environment, productivity and farm profit. Beyond the monitoring of the technical implementation, the scale-out strategy recommends the adoption of a high-level monitoring protocol that records the impacts at scale.

LESSONS LEARNED

The pilot project was designed to connect the various information and knowledge sources that have already been developed in Zambia but have not been consistently implemented. The main objective was to organize this existing knowledge and integrate effective water management practices into the sector's development process. Despite its significant potential, rice production in Zambia still has not reached expected levels. However, providing technical support and incentives for community-based development could accelerate improvement. Based on the design and findings, the following key messages can be concluded:

- Adaptive research should be implemented to relate development results to actual field conditions across various environments. The development of optimal practices often remains at the research level, as rice production regions in Zambia are not systematically organized, and the reach-out phase of the project must overcome the issue of remoteness. Transferring research results directly to farmers can help accelerate the adoption of new technologies. Therefore, introducing adaptive research as a bridge between research processes and the field can enhance the scale-out phase.

- Although the lack of irrigation practices is a major impediment to yield productivity, farmers have only a little understanding of its importance and role in rice production.

In Zambia, most irrigated areas belong to commercial farms. Irrigation system designs and methods are configured for commercial, large-scale production, which are not readily transferable to the smallholder context. As a result, smallholders are exposed to the rainfall pattern. Promoting small-scale and sustainable irrigation development for smallholders is crucial to enhancing their productivity levels and making production practices more resilient to climate extremes. Efforts in agriculture development should focus on feasibility assessment-based strategies for small-scale irrigation development in regions with high potential.

- Understanding both production requirements and benefits can help in evaluating whether rice production is a viable development direction for all interested communities. Rice production is not yet widely practised in Zambia, and many community-based initiatives rely on a trial-and-error approach without adequate training or sufficient information. Shifting to rice production involves financial risks for farmers, especially if production fails. As profitability is a key issue in sector development in the smallholder context, awareness-raising programmes should integrate discussions related to farm economics. As rice is resource-intensive and the costs of inputs exceed those of the traditional crops, optimal production practices must be complemented with cost–benefit analysis. To address this, efforts to increase capacity should begin with awareness-raising initiatives that ensure farmers understand the benefits and meet the prerequisites for rice production. Using pilots for demonstration purposes would provide evidence to equip farmers with the required information on benefits and prerequisites. Nevertheless, pilots are useful only to showcase the production practices. Smallholders require support to gain an overarching understanding of the entire value chain, including post-harvest handling. This can help prevent marketing challenges that directly stem from the compromised quality of grains.

- The creation of effective practices must be customized to account for varying resource capacities. This is because rice production spans different regions that fall under distinct agroecological zones. Community-driven development can facilitate this process. Rather than focusing on individuals, development efforts should target communities to promote collaboration, thereby enhancing economies of scale in production. This approach would enable farmers to systematically improve their production practices and gain easier access to markets.

For more information, please contact:
Eva Pek, Land and Water Officer, Land and Water Division
Komei Sasa, Junior Professional Officer, Land and Water Division
Annie Mwamba, Natural Resources Management Expert, FAO-Zambia
Maher Salman, Senior Land and Water Officer/ AWM Team Lead, Land and Water Division

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