



Original Research

Adoption Dynamics and Productivity Outcomes of an Integrated Wheat Support Package among Smallholder Farmers

Muhammad Khalid¹, Maryam Samad², Shehzad Elahi² and Shah Fahad^{1,*}

¹ Cereal Section, Agriculture Research Institute, Tarnab, Peshawar, 24330, Pakistan

² National Integrated Development Association (NIDA), University Town, Peshawar, Pakistan

* Corresponding author. Email: shahfahad@aup.edu.pk

Abstract

This study evaluated adoption and productivity outcomes of a Wadaan-17 support package among 125 farmers in District Khyber, Khyber Pakhtunkhwa, during the 2024-25 wheat season. Participants received certified Wadaan-17 seed, fertilizer inputs, technical orientation, field demonstrations, and follow-up support. Descriptive statistics were used to summarize farmer characteristics and adoption indicators, a paired-samples t-test compared grain yield before and after the intervention, and multivariable linear regression assessed factors associated with grain yield. Improved land preparation showed the highest adoption (94.4%) followed by certified wheat seed (86 %), improved irrigation practices (84.0%), line sowing (83.2%), and balanced fertilizer application (76.8%). Adoption was lower for improved seed storage (65.6%) and pest and disease management (57.6%). Mean grain yield increased from approximately 625 to 740 kg acre⁻¹, an increase of about 18%, and the paired comparison was significant ($t(124) = -11.54$, $p < 0.001$). However, as the study employed a before-and-after design without a same-season control group, the observed yield improvement should be interpreted as a before-and-after difference rather than a causal effect of the intervention. In the regression model, certified-seed adoption and improved-practice adoption had the largest positive coefficients among the reported modifiable predictors. The findings indicate strong uptake of several recommended practices and higher post-intervention yield, while also identifying seed storage and crop protection as areas requiring greater attention. Because certified seed, fertilizer and extension support were delivered together in a program design, the yield improvement should be interpreted as associated with the integrated intervention rather than certified wheat seed of Wadaan-17 alone.

Citation: Khalid, M., Samad, M., Elahi, S., & Fahad, S. (2026). Adoption Dynamics and Productivity Outcomes of an Integrated Wheat Support Package among Smallholder Farmers. *AgroEnvironmental Sustainability*, 4(3), 345–350. <https://doi.org/10.59983/s20260403011>

Statement of Sustainability: The sustainability relevance of this study lies in strengthening the productive capacity of smallholder wheat farming through an integrated approach that combines access to quality seed with practical agronomic guidance and continued extension support. Such an approach addresses important production constraints at the farm level by linking improved agricultural inputs with the knowledge required for their effective use. Within the scope of this study, the contribution is therefore most appropriately related to SDG 2 (Zero Hunger), particularly its emphasis on strengthening small-scale food production.

1. Introduction

Wheat (*Triticum aestivum* L.) is a major staple cereal in Pakistan and plays an essential role in national food security and rural livelihoods. Improving wheat productivity depends not only on the genetic potential of a cultivar but also on seed quality, crop establishment, nutrient management, irrigation, and the ability of farmers to adopt recommended practices. These factors are especially important in smallholder production systems, where limited access to reliable seed and technical support may restrict the expression of varietal yield potential.

Genetic improvement has contributed to wheat productivity in Khyber Pakhtunkhwa. Anas et al. (2026) evaluated genetic progress in bread-wheat cultivars released in the province and documented gains in grain yield and important yield-related traits over four

ARTICLE HISTORY

Received: 30 June 2026

Revised: 19 August 2026

Accepted: 05 September 2026

Published: 15 September 2026



KEYWORDS

certified seed
Khyber Pakhtunkhwa
smallholder farmers
technology adoption
Wadaan-17
wheat productivity

COPYRIGHT

© 2026 Author(s)

e-ISSN: 2583-942X

Exclusive Rights: Society for
AgroEnvironmental Sustainability,
Dehradun, India

LICENSE



This is an Open Access Article
published under a CC BY 4.0
International License



decades, with Wadaan-17 included among the improved cultivars assessed. Evidence specific to Wadaan-17 also demonstrates its agronomic potential. Ullah et al. (2022) evaluated 30 wheat genotypes across five environments in Khyber Pakhtunkhwa and reported significant genotype-by-environment interaction, with Wadaan-17 producing the highest mean grain yield among the tested genotypes. This variation across environments indicates that performance of an improved variety should also be examined under local farmers' conditions.

Agronomic management strongly influences the extent to which improved varieties achieve their yield potential. In Dera Ismail Khan, Khyber Pakhtunkhwa, Ranazai et al. (2024) showed that sowing method and seed rate significantly affected wheat growth, yield components, and grain yield, demonstrating the importance of locally appropriate crop-establishment practices. Recent experimental evidence from Pakistan also shows that input delivery becomes more effective when it is linked with practical extension. Hussain and Maharjan (2025) found that supervised on-farm demonstrations increased certified-seed use and adoption of recommended practices and resulted in sustained improvements in wheat yield and profitability. Their findings support extension approaches that combine quality seed with farmer training, demonstrations, and follow-up rather than relying on seed distribution alone.

District Khyber provides an important setting for evaluating such an integrated approach because irrigation potential is spatially variable and rainfed agriculture remains vulnerable in parts of the district (Waleed et al., 2020). Under the project "Building Resilience Through Improved Nutrition in Sub-Urban Food Systems in KP (Pak 1136)," 125 farmers received certified Wadaan-17 seed, fertilizer, technical orientation, field demonstrations, and follow-up support during the 2024-25 wheat season (NIDA Pakistan, n.d.). The present study assessed participant characteristics and irrigation access, adoption of recommended agronomic practices, changes in grain yield following the intervention, and factors associated with grain-yield outcomes. Therefore, while previous studies have demonstrated the genetic potential of Wadaan-17 and the importance of agronomic management, there remains limited evidence on how smallholder farmers in District Khyber adopt such integrated support packages under real-world conditions. Building on this gap, the present study was designed to systematically assess adoption dynamics and productivity outcomes of the Wadaan-17 wheat support package among smallholder farmers in District Khyber, Pakistan. The objectives of the present study were; i) to document farmer characteristics and irrigation access; ii) to evaluate adoption rates of certified seed and recommended agronomic practices; iii) and to compare grain yield before and after the intervention while identifying factors associated with yield outcomes through regression analysis.

This intervention was performed with the hypothesis that provision of certified Wadaan-17 seed combined with agronomic guidance and extension support would lead to higher adoption of recommended practices and a statistically significant improvement in wheat grain yield compared to farmers' pre-intervention performance.

2. Materials and Methods

2.1. Study Area, Design and Participants

The intervention was implemented in District Khyber, Khyber Pakhtunkhwa, Pakistan, during the 2024-25 wheat season under project Pak 1136. Activities were conducted across 10 village or neighborhood council areas. District Khyber has semi-arid conditions and variable irrigation potential, making access to water an important part of the local production context. Geographically, District Khyber is located at approximately 34°01'12"N, 71°25'48"E, with elevations ranging from 450 to 1,200 meters above sea level. The study used project-monitoring data from 125 farmers who participated in the Wadaan-17 demonstration activity. Participants were selected according to project eligibility criteria with support from Community-Based Organizations and Village Organizations and verification by project staff. Eligibility included permanent residence in the target area, smallholder or vulnerable-household status, access to land and irrigation water, willingness to manage a demonstration plot, and commitment to participate in crop-production and knowledge-sharing activities. The sample therefore represents participating project farmers rather than a random sample of all farmers in District Khyber.

2.2. Intervention Package and Data Collection

All participating farmers received 50 kg certified seed of Wadaan-17 wheat variety along with recommended dose of urea, diammonium phosphate (DAP) and sulphate of potash (SOP) for one acre wheat. Technical sessions covered land preparation, seed selection, crop nutrition, irrigation, line sowing, pest management, and pre- and post-harvest handling. Follow-up consisted of farmer guidance, field visits, and three field days conducted at key crop stages in collaboration with Agriculture Extension department.

Baseline informations were collected from the participating farmers before implementation of the intervention. Baseline records included farmer age, farming experience, formal education, landholding, irrigation source, and pre-intervention wheat grain yield. Pre-intervention grain yield was obtained from participating farmers based on their reported yield from the most recent wheat season before programme participation and was compared with post-intervention grain yield recorded after implementation of the intervention. Post-intervention monitoring further documented adoption of certified wheat seed, improved irrigation practices,



line sowing, balanced fertilizer application, improved land preparation, pest and disease management, and improved seed storage practices. Grain yield differences before and after the intervention were assessed using paired analysis, while the multivariable model examined associations between grain yield and farmer characteristics, irrigation variables, seed adoption and other practices adoption.

2.3. Statistical Analysis

Descriptive statistics were used to summarize farmer characteristics, irrigation sources, and adoption of improved agricultural practices. Continuous variables were presented as means, while categorical variables were reported as frequencies and percentages. For regression analysis, improved-practices adoption was treated as a binary variable (Yes/No) based on farmers recorded use of the promoted agronomic practices, including improved land preparation, improved irrigation, line sowing, balanced fertilizer application, pest and disease management, and improved seed storage. Certified-seed use was treated separately because it was entered as an independent predictor in the regression model. A farmer was classified as “Yes” when all six specified practices were recorded as adopted; otherwise, the farmer was classified as “No.” Grain yield before and after the intervention was compared using a paired-samples t-test. Multivariable linear regression was used to examine factors associated with grain yield. Grain yield was used as the dependent variable in its original measurement unit (kg acre^{-1}); no logarithmic transformation, standardization, or rescaling was applied before regression analysis. Regression results were expressed as unstandardized coefficients (B), standard errors, 95% confidence intervals, and p-values. Statistical significance was considered at $p < 0.05$. A significance level of $p < 0.05$ was used for individual tests; no adjustment for multiple comparisons was applied, and this limitation is acknowledged in the interpretation of the findings.

3. Results and Discussion

3.1. Participant Characteristics and Irrigation Access

The participating farmers had a mean age of 39.9 ± 14.8 years, mean farming experience of 20.3 ± 6.5 years, mean formal education of 8.0 ± 4.3 years, and mean landholding of 3.5 ± 1.0 acres. Regarding irrigation access, canal irrigation was the most common water source, reported by 109 farmers (87.2%). A further 11 farmers (8.8%) used combined canal and tube-well irrigation, while 5 farmers (4.0%) relied on rainfed production (Table 1).

Table 1. Baseline characteristics of participating farmers (N = 125).

Characteristic	Mean $\pm$ SD or n (%)
Age (years)	39.9 ± 14.8
Farming experience (years)	20.3 ± 6.5
Formal education (years)	8.0 ± 4.3
Landholding (acres)	3.5 ± 1.0
Canal irrigation	109 (87.2%)
Canal + tube-well irrigation	11 (8.8%)
Rainfed	5 (4.0%)

The participant profile is relevant to adoption because farming experience, landholding, irrigation and extension contact have been associated with improved wheat variety adoption in Pakistan (Chandio and Jiang, 2018). However, the present participants were selected according to project eligibility criteria that included access to land and irrigation water, willingness to manage a demonstration plot, and commitment to participate in project activities. Therefore, this sample should not be considered representative of all farmers in District Khyber. The predominance of canal irrigation and the adoption patterns reported here are most appropriately interpreted for farmers with characteristics and resource access similar to those participating in the project, particularly because irrigation potential varies substantially across District Khyber (Waleed et al., 2020).

3.2. Adoption of Certified Seed and Recommended Practices

Post-intervention monitoring showed high uptake of several practices promoted during the intervention. Improved land preparation (94.4%, 118 farmers) had the highest adoption, followed by certified seed (86.0%, 107 farmers), improved irrigation practices (84.0%, 105 farmers), line sowing (83.2%, 104 farmers), and balanced fertilizer application (76.8%, 96 farmers). Adoption was lower for improved seed storage (65.6%, 82 farmers) and pest and disease management (57.6%, 72 farmers) (Table 2). Because certified seed, fertilizer inputs, training, and follow-up support were provided together through the programme, adoption outcomes should be interpreted as programme-associated uptake rather than independent adoption decisions.

Farmers linked the lower uptake of improved seed storage to limited access to suitable storage facilities, reliance on traditional methods, and the additional cost involved. Similarly, lower uptake of pest and disease management was associated with difficulty



in timely problem identification, limited access to crop-protection inputs, and uncertainty regarding correct treatment. These findings suggest that future extension should emphasize practical, low-cost storage options and stronger hands-on support for pest and disease diagnosis and management.

The high uptake of certified seed and core crop-management practices is consistent with evidence that practical extension accelerates technology adoption. In a Pakistan-based natural experiment, supervised on-farm demonstrations increased certified-seed use by 34% and improved wheat yield relative to the comparison group (Hussain & Maharjan, 2025). Chandio & Jiang (2018) similarly identified extension contact as a significant positive factor in the adoption of improved wheat varieties.

Seed storage and pest and disease management remained the two least-adopted practices. Saeed et al. (2020) documented inadequate wheat-seed storage conditions and gaps in farmer awareness in Pakistan, supporting the need for stronger post-harvest guidance. The lower uptake of crop protection in the present study also indicates that future extension should give greater attention to field scouting, timely diagnosis, and appropriate management decisions.

Table 2. Pre-intervention vs. Post-intervention adoption of certified wheat seed and improved agricultural practices (N = 125).

Agricultural practice	Pre-intervention adoption	Post-intervention adoption	Improvement (percentage points)
Improved land preparation	70.3% (88 farmers)	94.4% (118 farmers)	+24.1
Certified wheat seed	45.5% (57 farmers)	86.0% (107 farmers)	+40.5
Improved irrigation	72.5% (91 farmers)	84.0% (105 farmers)	+11.5
Line sowing	48.5% (61 farmers)	83.2% (104 farmers)	+34.7
Balanced fertilizer	43.5% (54 farmers)	76.8% (96 farmers)	+33.3
Improved seed storage	44.3% (55 farmers)	65.6% (82 farmers)	+21.3
Pest & disease management	39.5% (49 farmers)	57.6% (72 farmers)	+18.1

3.3. Grain Yield Comparison Before and After the Intervention

The paired comparison was statistically significant ($t(124) = -11.54$, $p < 0.001$). Mean grain yield increased from approximately 625 kg acre⁻¹ before the intervention to approximately 740 kg acre⁻¹ after the intervention (Figure 1). This represents an increase of about 115 kg acre⁻¹, or approximately 18%.

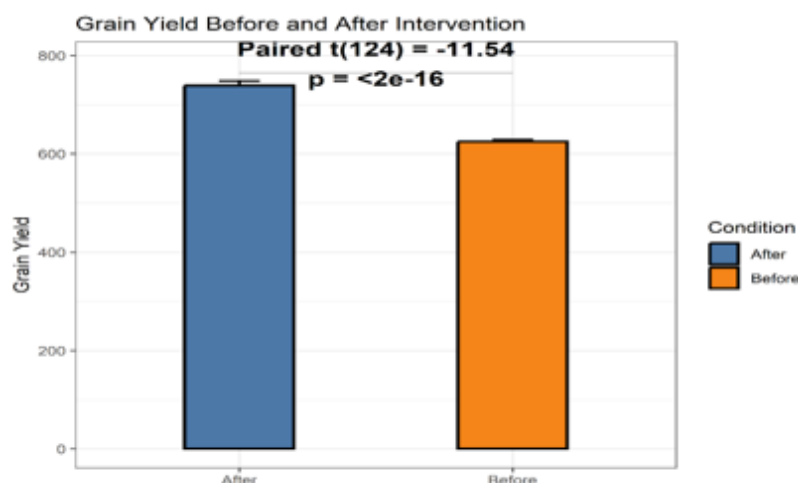


Figure 1. Grain yield before (use of uncertified seed of conventional varieties) and after the intervention (use of certified seed of Wadaan-17).

The direction of the yield change agrees with previous Pakistan evidence on improved varieties and certified seed. Joshi et al. (2016) reported that new wheat varieties grown from certified seed produced 33.8% more grain yield than old farmer varieties grown from farmer-saved seed in on-farm trials. Wadaan-17 also recorded the highest mean grain yield (4330.8 kg ha⁻¹) among 30 genotypes tested across five Khyber Pakhtunkhwa environments, although its performance varied by location (Ullah et al., 2022). Ranazai et al. (2024) further showed that sowing method significantly affects wheat yield in Khyber Pakhtunkhwa, supporting interpretation of the present increase as the outcome of the combined seed-and-management intervention rather than seed alone. It should be noted that the post-intervention yield of approximately 740 kg acre⁻¹ ($\approx 1,800$ kg ha⁻¹) observed in this study is considerably lower than the 4,330 kg ha⁻¹ reported for Wadaan-17 in multi-location experimental trials (Ullah et al., 2022). This



discrepancy reflects differences between experimental conditions and smallholder farmer fields. In the present study, yields were based on farmer-reported baselines and monitored plots under variable irrigation access, heterogeneous management capacity, and resource constraints. By contrast, Ullah et al., (2022) evaluated genotypes under replicated trials with optimal management and uniform plot conditions. The lower yields observed here therefore highlight the gap between varietal potential and realized productivity under real-world smallholder circumstances, underscoring the importance of integrated extension support to narrow this gap.

3.4. Factors Associated with Grain Yield

The multivariable linear regression model was statistically significant ($F(6,118) = 25.95, p < 0.001$), explaining 56.9% of the variation in grain yield ($R^2 = 0.5689$; adjusted $R^2 = 0.5470$). Farming experience showed a significant positive association with grain yield ($t = 6.288, p < 0.001$). Certified-seed adoption ($t = 3.487, p = 0.0007$) and improved-practice adoption ($t = 4.355, p < 0.001$) were also significant positive predictors. In contrast, age was not significantly associated with grain yield ($p = 0.6818$). Likewise, neither rainfed conditions ($p = 0.1561$) nor tube-well irrigation ($p = 0.6150$) differed significantly from the canal-irrigation reference category after adjustment for the other predictors (Table 3).

The significant effects of farming experience, certified seed, and improved-practice adoption indicate that both farmer knowledge and technology uptake were important contributors to productivity. The positive association with certified-seed use is consistent with Joshi et al. (2016), who reported higher wheat yield from improved varieties grown with certified seed. Similarly, the significance of improved-practice adoption supports Hussain and Maharjan (2025), who demonstrated that combining quality seed with supervised demonstrations and recommended agronomic practices can improve wheat performance. These findings suggest that productivity gains are better supported through an integrated seed-and-management approach rather than through seed provision alone.

Multicollinearity diagnostics further supported the stability of the regression model. Adjusted GVIF values ranged from 1.0151 for irrigation source to 1.3753 for farming experience, while certified-seed adoption and improved-practice adoption had adjusted GVIF values of 1.0850 and 1.0786, respectively. Because all adjusted GVIF values were close to 1, there was no evidence of serious multicollinearity among the explanatory variables (Table 4).

Table 3. Multivariable linear regression of factors associated with grain yield.

Variable	Estimate (β)	Std. Error	t-value	p-value	Significance
(Intercept)	2.1178	0.4350	4.869	< 0.001	***
Age	0.4195	0.0102	0.411	0.6818	
Farming Experience	2.6040	0.0165	6.288	< 0.001	***
Irrigation Source: Rainfed (Ref: Canal)	-0.3541	0.2481	-1.428	0.1561	
Irrigation Source: Tubewell (Ref: Canal)	0.1036	0.2055	0.504	0.6150	
Certified Seed Adoption: Yes (Ref: No)	3.7157	0.2052	3.487	0.0007	***
Improved Practice Adoption: Yes (Ref: No)	2.8610	0.1977	4.355	< 0.001	***

Note: Model Fit: $R^2 = 0.5689$, Adjusted $R^2 = 0.5470$, $F(6, 118) = 25.95, p < 0.001$, Residual Standard Error = 1.01. Significance levels: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$. Canal irrigation was used as the reference category for the irrigation-source variable. Therefore, the coefficients for canal + tube-well irrigation and tube-well irrigation are interpreted relative to canal irrigation.

Table 4. Multicollinearity Diagnostics (GVIF).

Predictor Variable	GVIF	Df	Adjusted GVIF $^{1/(2 \times Df)}$	Multicollinearity Assessment
Age	1.6350	1	1.2787	Low / No Concern
Farming Experience	1.8913	1	1.3753	Low / No Concern
Irrigation Source	1.0616	2	1.0151	Low / No Concern
Certified Seed Adoption	1.1773	1	1.0850	Low / No Concern
Improved Practice Adoption	1.1633	1	1.0786	Low / No Concern

Note: Adjusted GVIF values close to 1 indicate that serious multicollinearity is not present among the explanatory variables.

4. Conclusions and Recommendations

The Wadaan-17 intervention reached 125 smallholder farmers in District Khyber and was followed by high adoption of certified wheat seed, improved land preparation, irrigation and line sowing. Mean grain yield increased by approximately 18% after the intervention, and the regression results showed strong positive associations for certified-seed and improved-practice adoption. However, seed storage and pest and disease management had comparatively lower uptake, indicating areas where additional technical support is needed. These findings are preliminary and associational rather than causal because the yield analysis used a before-and-after comparison without a same-season control group. In addition, seed and extension support were delivered as one



package; therefore, the contribution of Wadaan-17 cannot be separated from the effects of crop management, extension support, or seasonal conditions. Future studies should use a contemporaneous comparison design to assess the independent effects of intervention components.

Author Contributions

Muhammad Khalid: Software, Writing – original draft, Writing – review and editing; Maryam Samad: Conceptualization, Methodology, Investigation, Data curation; Shehzad Elahi: Conceptualization, Investigation, validation, Resources; Shah Fahad: Software, Visualization, Writing – original draft, Writing – review and editing.

Acknowledgements

The authors acknowledge the participating farmers, Community-Based Organizations, Village Organizations, NIDA Pakistan field and MEAL staff, Agriculture Research and Extension department and Welthungerhilfe (WHH), Germany, for their roles in implementation and support of the field activity.

Funding

The field activity was implemented under the project “Building Resilience Through Improved Nutrition in Sub-Urban Food Systems in KP (Pak 1136)” with the financial support from Federal Ministry for Economic Cooperation and Development, Germany.

Declarations

Conflicts of Interest: The authors declare no conflict of interest.

Institutional/Ethical Approval: This study did not involve human or animal subjects and no institutional or ethical approval was required.

References

- Anas, M., Khan, K., Ali, H., Rahman, A. U., Raza, M. A., Wahab, A. U., Taimur, M., Afridi, M. S., and Khalil, I. H. (2026). Genetic gain in yield and yield-related traits of bread wheat over the past 40 years in Khyber Pakhtunkhwa. *Sarhad Journal of Agriculture*, 42(1), 262–276. <https://doi.org/10.17582/journal.sja/2026/42.1.262.276>
- Chandio, A. A., and Jiang, Y. (2018). Factors influencing the adoption of improved wheat varieties by rural households in Sindh, Pakistan. *AIMS Agriculture and Food*, 3(3), 216–228. <https://doi.org/10.3934/agrfood.2018.3.216>
- Hussain, N., and Maharjan, K. L. (2025). Impact of on-farm demonstrations on technology adoption, yield, and profitability among small farmers of wheat in Pakistan—An experimental study. *Agriculture*, 15(2), 214. <https://doi.org/10.3390/agriculture15020214>
- Joshi, K. D., Rehman, A. U., Ullah, G., Baloch, A., Hussain, M., Ahmad, J., Ishaq, M., Ahmad, G., Ahmad, N., Abbas, S. H., Qamar, M., Ahmad, M., Dar, A. I., Khokhar, B., Sajid, M., Hussain, A., and Imtiaz, M. (2016). Yield and profit from new and old wheat varieties using certified and farmer-saved seeds. *Journal of Agricultural Science and Technology B*, 6(3), 141–150. <https://doi.org/10.17265/2161-6264/2016.03.001>
- Ranazai, S. K., Sadiq, M., Baloch, M. S., Qureshi, H., Anwar, T., Alarfaj, A. A., and Ansari, M. J. (2024). Impact of different priming and sowing techniques in combination with different seed rates on wheat growth and yield. *Scientific Reports*, 14, 26726. <https://doi.org/10.1038/s41598-024-78256-y>
- Saeed, M. F., Jamal, A., Ahmad, I., Ali, S., Shah, G. M., Husnain, S. K., Farooq, A., and Wang, J. (2020). Storage conditions deteriorate cotton and wheat seeds quality: An assessment of farmers' awareness in Pakistan. *Agronomy*, 10(9), 1246. <https://doi.org/10.3390/agronomy10091246>
- Ullah, I., Raza, H., Ali, S., Fahad, S., Ahmad, A., Mukhtiar, S., Samad, N., and Babar, M. (2022). Stability and yield performance of different wheat genotypes across multi-locations of Khyber Pakhtunkhwa. *Pure and Applied Biology*, 11(3), 793–805. <https://doi.org/10.19045/bspab.2022.110080>
- Waleed, M., Ahmad, S. R., Javed, M. A., and Samiullah, S. (2020). Identification of irrigation potential areas, using multi-criteria analysis in Khyber District, Pakistan. *Environmental Science and Pollution Research*, 27(32), 39832–39840. <https://doi.org/10.1007/s11356-020-08967-y>

Publisher's note/Disclaimer: Regarding jurisdictional assertions in published maps and institutional affiliations, We maintains its neutral position. All publications' statements, opinions, and information are the sole responsibility of their respective author(s) and contributor(s), not We or the editor(s). We and/or the editor(s) expressly disclaim liability for any harm to persons or property caused by the use of any ideas, methodologies, or products described in the content.