Framework for Valuing the Effects of Irrigation Project on Economy, Society and Environment: Evidence from Ganges-Kobadak Irrigation Project

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ABSTRACT

The Ganges-Kobadak Irrigation Project (GKIP) is a major surface water irrigation initiative in Bangladesh, designed to enhance agricultural productivity, socioeconomic development, and water management in the southwestern region's catchment area. While large-scale irrigation projects like GKIP are often criticized for environmental and social drawbacks—such as biodiversity loss and community displacement—they also deliver significant socioeconomic benefits. This study develops a holistic framework to evaluate the socioeconomic and ecological impacts of such projects on local communities. Employing a descriptive research design, a cross-sectional household survey was conducted in March–April 2025, collecting primary data from 180 households in GKIP beneficiary communities across Kushtia district using convenience sampling. Key findings reveal that 77.8% of households reported increased crop yields, 65.6% noted improved irrigation access, and 73.3% observed enhanced income-generating opportunities, underscoring GKIP's role in boosting agricultural output and livelihood diversification. Stakeholder perceptions of Nature's Contributions to People (NCP) emphasized high valuation of rural connectivity (27.8% rated it extremely important) and agro-biodiversity (25%), while regulating services such as pest and disease control (48.9% deemed not at all important) and habitat creation (22.8%) were undervalued. These outcomes highlight the need for targeted environmental education and inclusive community engagement. The study provides critical insights into GKIP's multifaceted impacts and advocates for integrating local perspectives into irrigation policy to ensure sustainable and equitable resource management. Its novel contribution lies in proposing a comprehensive valuation framework for large-scale irrigation projects, emphasizing the alignment of sustainable practices with economic growth, social equity, and environmental conservation to advance Sustainable Development Goals (SDGs). Future research should empirically validate the proposed framework across diverse contexts.

Keywords: agricultural production, irrigation project, GKIP, valuation framework, Bangladesh

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INTRODUCTION

The irrigation project seems crucial in reducing rural poverty by augmenting agricultural production (Higginbottom et al., 2021; Hussain, 2007). While the debate exists about the economic viability of large-scale irrigation projects, the decades-old practice of large irrigation projects still draws much attention from social advocacy groups, academics, and aid agencies globally (Higginbottom et al., 2021). The irrigation project is mainly criticized for its negative impact on the environment and society which is evident in many parts of the globe (Plusquellec, 2019; Suhardiman & Giordano, 2014). For instance, a large dam construction may significantly alter the local biodiversity and force local inhabitants to relocate (Galbraith, 2005). The large irrigation project is also blamed for overtaking huge land areas and often destroying massive wetlands (Barros-Rodríguez et al., 2021; Galbraith, 2005). According to the Organization for Economic Co-operation and Development (OECD) "The world may have lost 50 percent of the wetlands that existed since 1900; whilst much of this occurred in the northern countries during the first 50 years of the century, increasing pressure for conversion to alternative land use has been put on tropical and sub-tropical wetlands since the 1950s" (OECD, 1996). In the same vein, Otsuka et al. (2023) claim that growing environmental and social concerns worked against large-scale new projects involving large dam construction and the relocation of inhabitants.

Studies support that large irrigation projects are often problematic to understand because of their poor design, less knowledge about local conditions, inefficient technology choices, poor selection of operation mechanisms, and bureaucratic red-tapism in operation and management (Otsuka et al., 2023; Biswas, 1986). Similarly, the high cost of construction and operation but the low performance of large irrigation projects makes it a vulnerable choice to policymakers (Inocencio et al., 2007). However, large irrigation projects often appear as a means that ensure the reliability of agricultural production or food security and enhance income generation for beneficiaries (Kassie & Alemu, 2021). Hence, despite continuous debate about large-scale irrigation projects, many projects have been constructed in many countries hoping to improve agricultural production and combat food vulnerability (Rudolf, 2014). For instance, Indonesia has recently built an irrigation project with a cost of $156 million aiming to increase food production on some 59,340 ha. stimulate employment in the project area, control damaging floods in rural and urban areas, supplement water supplies for some 300 villages and towns, generate 74 GWh of power which would be fed into the national grid, and improve water management in the project area (World Bank, 2023).

Continuous debates on irrigation projects highlight their significance as a critical research domain for re-exploring the benefits and costs of implementing such large-scale initiatives. Moreover, the long-term operation and maintenance of these projects often relay on taxpayer funding, which necessitates demonstrable benefits for their intended beneficiaries. However, the scarce of evidence relating post-implementing studies on such projects poses challenges for securing future financing. In the case of the Ganges-Kobdak Irrigation Project (GKIP), most existing studies have focused on its impacts on agricultural productivity and community wellbeing (Goes, Clark & Bashar, 2020; IMED, 2014; Ali, 2001; Andreou, 1979), these studies, however, are constrained by methodological and scope limitations.

Given the importance of agro-biodiversity, agricultural production, and rural roads and communication in Bangladesh, there is a pressing need for robust empirical evidence to guide policymakers. Such evidence could support and encourage large-scale irrigation projects in the context of climate change risks and growing concerns over future food-grain vulnerabilities. This study advances the scholarly discourse on large-scale irrigation systems by developing a multidimensional conceptual framework to holistically evaluate the social, economic, and environmental impacts of the Ganges-Kobadak Irrigation Project (GKIP). Grounded in a systematic synthesis of peer-reviewed studies, government reports, and field surveys, the framework integrates qualitative and quantitative indicators to address gaps in existing impact assessment methodologies. To validate its applicability, the theoretical model is supplemented by empirical evidence derived from a descriptive study conducted across project areas in-part, incorporating primary data from household surveys.

OBJECTIVE

The main purpose of this paper is to develop and apply a multidimensional conceptual framework for evaluating the social, economic, and environmental impacts of the Ganges-Kobadak Irrigation Project (GKIP) in Bangladesh, integrating empirical evidence to inform policy decisions on sustainable large-scale irrigation development. Following are the specific objectives:

1. To develop a valuation framework for large scale irrigation project,
2. To assess the social, economic and environmental impacts of GKIP,
3. To generate empirical evidence through household surveys and field data to validate the proposed framework partially, and
4. To propose recommendations for the policymakers in addressing climate change and agro-biodiversity concerns.

LITERATURE REVIEW

Valuing the Benefits of Irrigation Project

Studies show that large-scale irrigation projects associated with both costs and benefit (Michailidis et al., 2009). After the implementation of the project, the scenario of the area that is covered by the project started to largely change (Aruna Shantha & Asan, 2014; Omondi, 2014). It has brought a comprehensive benefit in the area of socioeconomic and sociocultural results, economic revolution, financial performance, institutional performance, and women in development (Bashe et al., 2024). The following sub-section elaborates the specific impact of large irrigation project on various dimensions.

Social Benefits

Large-scale irrigation projects have been shown to yield significant social benefits for the communities they serve. One primary advantage is the improvement in living standards. For instance, the availability of reliable water sources through irrigation can enhance food security by ensuring consistent agricultural productivity, which is crucial for rural populations (Barros-Rodríguez et al., 2021; Galbraith, 2005). Historically, large irrigation projects have a pivotal role in driving the Green Revolution in many parts of the world. The remarkable growth was achieved through the adoption of high-yielding crop varieties,

increased cropping intensity, and crop rotation, all of which were facilitated by these irrigation projects. Increased agricultural productivity has resulted in higher incomes, improved living standards, better health outcomes, and enhanced investment in education, ultimately helping communities escape poverty (Higginbottom et al., 2021; Hagosa et al., 2011).

However, despite greater engagement in productive activities, the persistent gap in productivity between efficient and inefficient farmers within the same irrigation area raises concerns about the project's overall impact on poverty reduction (Hussain & Hanjra, 2003). Large irrigation project brings social benefit by generating diverse economic opportunities for both men and women. Socially vulnerable women, in particular, have increasingly participated in agriculture-related economic activities, contributing to household decision-making and fostering gender equality and resilience (Hussain, 2007). Another important social benefit is the strengthening of community ties through the shared use of common resources, which has promoted cooperation, social inclusion, and collective action for community improvement (Inocencio et al., 2007). However, the shared utilization of common resources can sometimes lead to conflicts of interest, resulting in community divisions and factional polarization.

Economic Benefits

Large irrigation projects bring numerous economic benefits to households in the catchment areas. Studies have shown that agricultural productivity increases significantly due to irrigation projects, leading to higher crop yields, the cultivation of high-value crops, and year round farming enabled by a stable water supply (Michailidis, 2006). Farmers can diversify their crop cultivation and adopt a wider variety of crops by mitigating the risks associated with natural climatic variability through consistent water supply. Increased agricultural activities create many informal job opportunities for rural poor. Both direct and indirect employment opportunities emerge in agriculture-related sectors, such as agro-based industry, fish farming and livestock rearing contributing to increased household incomes and improved living standards. Additionally, higher agricultural production stimulates rural growth centers to operate at full capacity, fostering trade and commerce and driving overall improvement in the rural economy.

The local economy is boosted through vibrant markets, job creation, and rising labor wages. Similarly, large irrigation projects require a substantial workforce and equipment for operation and maintenance, ensuring the integration of capital and labor resources into irrigation areas. Higher agricultural production fosters the development of forward-linkage industries supported by agro-products. For example, the Kushtia district in Bangladesh hosts hundreds of rice mills (both automated and conventional) to meet the country's rice demand. Additionally, food and beverage industries, storage facilities, and other linked economic activities have increased. Land value appreciates due to the heightened demand for fertile land in irrigated areas, benefiting landowners with improved property values and enabling them to capitalize on this value for investments in other sectors (Omondi, 2014). The multiplier effect of rising land values further spurs additional economic activities and investments in the region. Collectively, these projects generate direct economic benefits through increased agricultural production, employment creation, and surplus land value

(Kassie & Alemu, 2021; Omondi, 2014). Together, these factors positively impact both rural and national economies.

Environmental Benefits

Empirically, large-scale irrigation projects, when properly managed, can offer several environmental benefits alongside their economic and social advantages (Otsuka et al., 2023). One key environmental benefit is the improvement in soil quality. Irrigation helps to maintain soil moisture at optimal levels, which can prevent soil erosion and degradation. Consistent water supply enables the growth of cover crops and other vegetation, which protect the soil surface and contribute to soil health (Suhardiman & Giordano, 2014). Another significant benefit is the potential for groundwater recharge. In some irrigation systems, excess water percolates through the soil, replenishing aquifers and contributing to the sustainability of groundwater resources (Soonthornsima, n.d.). This process is particularly beneficial in regions where groundwater levels have been depleted due to over-extraction. Moreover, such irrigation systems help enrich large biodiversity through consisting of numerous water canals flanked by vegetation on both sides, which host diverse flora and fauna. This vegetation fosters a new agro-biodiversity along the canal system, contributing to climate regulation through carbon sequestration. Ponds and buffer zones that retain water year-round support wetland habitats, promoting diverse aquatic resources and terrestrial species (Rudlof, 2014). The rich agro-biodiversity also benefits local wildlife, as the canals, with roads on both sides, allow various tree species to thrive. These trees, in turn, host a variety of wild birds, creating a new ecosystem within the project area. However, concerns remain regarding water management in such projects, as they utilize millions of cubic meters of surface water (Thrikawala et al., 2022).

GK-Irrigation Project

A limited number of studies (see table 1) have found on the GK irrigation project which have looked at various aspects such as water allocation (Goes et al., 2020), management of irrigation system (Ali, 2001), economic appraisal (Andreou, 1979), and impact evaluation (IMED, 2014). Among the available studies, implementation monitoring and evaluation division IMED (2014) have conducted an impact evaluation without using inferential statistics. Their report revealed that the G-K irrigation system has significantly impacted various aspects of the community. Employment opportunities have notably increased in areas with adequate water supply. This is particularly evident in agro-industry, transportation, crop production, and agro-processing industries. According to report, the focus group discussion (FGD) participants confirmed that there has been a marked rise in employment opportunities in agricultural labor, processing, transporting, and marketing agricultural products. The scope of work in processing agricultural products has expanded, with activities such as rice hauling, flour milling, and home-based processing, where women are predominantly involved. Additionally, a substantial number of people are employed in transporting agricultural products for processing or marketing.

According to the report, the project has positively influenced fish production. Prior to the implementation of the GKIP, local fish farming was challenging due to the drying up of ponds. However, the post-implementation of GKIP ensures year-round water retention in

pond, significantly raise fish production in the catchment areas. This increase in fish production has further enhanced farmers' income. The GKIP has also benefited local communities by offering multiple economic opportunities, promoting joint-venture farming, and introducing new farming models supported by the canal system, which has led to significant increases in household incomes and improved living standards. Study participants confirm that the GKIP has enabled them with better housing and social status. However, many of the households are looking for better opportunities.

TABLE 1. AVAILABLE STUDY ON GK PROJECT IN AUTHENTIC DATABASES

Author (Year)	Title	Key Findings	Database
Goes, Clark & Bashar (2020)	Water allocation strategies for meeting dry-season water requirements for Ganges Kobadak Irrigation Project in Bangladesh	The mean Ganges River flow at Hardinge Bridge during the core of the dry season (February–April) has been 45% lower during the current Ganges Treaty period (1997–2019) than before the Farakka Barrage (1910–1975).	Scopus
Ali (2001)	Irrigation Management Issues in Bangladesh: Experiences and Lessons from Ganges-Kobadak Irrigation System	To function effectively, the scheme requires proper operation and maintenance of the main system, as well as an efficient use of water by farmers.	Google Scholar
Andreou (1979)	Economic appraisal of irrigation co-operatives in agricultural development in Ganges-Kobadak project, Bangladesh	The project has allowed considerable progress to be made in the establishment of new irrigation schemes and, as a result, the productivity and intensity of cropping has much improved.	Scopus
IMED (2014)	Impact Evaluation of the Project "Urgent Rehabilitation of Pumping Facilities of G-K Irrigation Project for Sustaining Rural Economic Development (1st Revised)"	The GKIP have started bringing positive impacts on food production' employment and living standards of the community.	Ministry of Planning, BD

Source: Authors Compilation

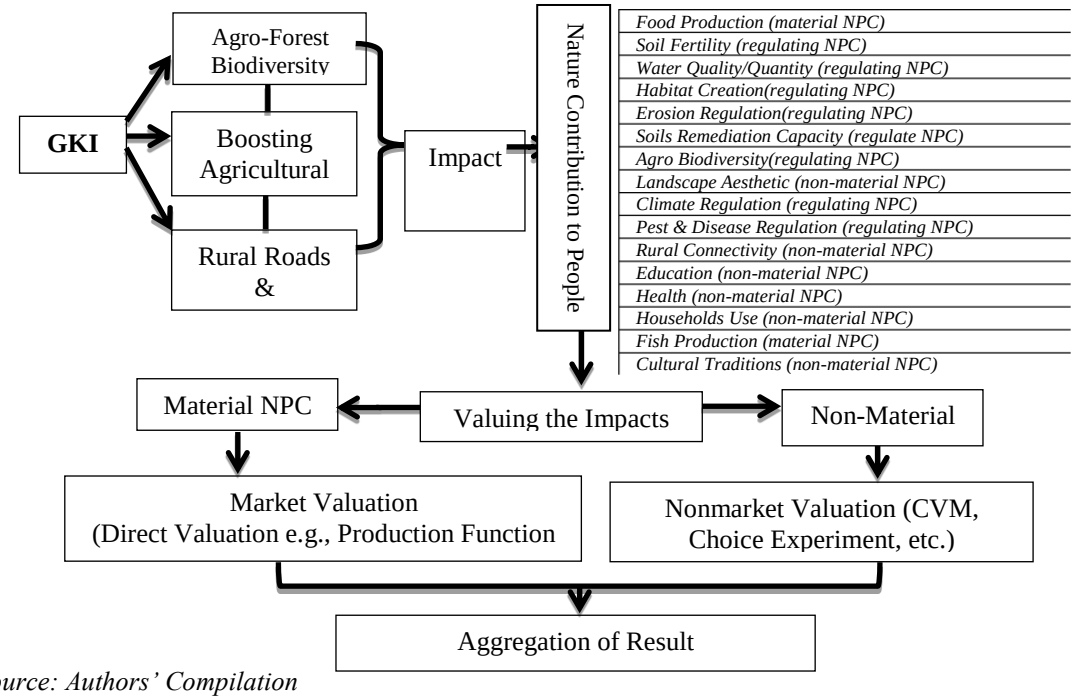
Moreover, the report summarizes that the GKIP has had a crucial impact on education and health. Although the impact study could not establish a direct correlation between catchment area and literacy rate, many households reported an increase in literacy within their family. Health outcomes have also likely improved due to enhanced road connectivity, which provides easier access to medical center. Additionally, the cherished infrastructure has enabled social interaction, commodity transportation, access to educational institutions, and visit to nearby markets, all linked to roads adjacent to the GKIP canal system. Together these attributes contribute to cumulative social benefits within the catchment areas, illustrating the positive impact of GKIP. However, the report is based on qualitative assumptions and lacks the underlying components of valuation studies. Project like GKIP should be valued incorporating social, economic and environmental dimensions. Goods and

services of intangible or non-market in types associated with this project, which were overlooked in the IMED study, must also be taken into account. Solely relying on value-in-use fails to capture the full scope of the project's impact. Additionally, the absence of control and treatment groups limits the ability to compare how households in different locations have benefited. To address these gaps, this paper proposes a valuation framework for GKIP, which can be validated through future empirical investigations.

Developing a Valuation Framework for GKIP

The proposed framework primarily focuses on nature's contribution to people (NPC), as suggested by Albizua et al. (2019). This study adapts several indicators under three key components: material NPC, non-material NPC, and regulating NPC. Material NPCs refers to tangiable benefits directly derived from the irrigation project, which can often be priced in the market and hold significant economic value. Examples in the GKIP area include food and fish production. Food and fish production can be assessed by estimating the increase in crop yields and calculating the additional income generated using market prices. Similarly, fish production can be valued by estimating the additional income from increased fish harvests, using market prices to determine its economic value. Non-material NPCs, on the other hand, are intangible benefits that enhance social and cultural well-being, which are often not captured by traditional economic markets. In such cases, non-market valuation methods may be more appropriate for assessing the value of various goods and services provided in the GKIP area.

FIGURE 1. FRAMEWORK FOR VALUING GKIP



Source: Authors' Compilation

Regulating NPC are those of non-priced goods and services that can be estimate using various non-market methods such as the contingent valuation method (CVM), replacement cost method (RCM), choice experiment method (CEM) etc. The GKIP is serving a climate regulator by maintaining the groundwater recharge and sequestering carbon dioxide through its large vegetation. The regulating NPC for climate change can be measured through the amount of carbon dioxide sequestered by vegetation supported by irrigation. Estimation can be done using market prices for carbon credits to determine the economic value of this climate regulation service. Based on the valuation results, formulate policy recommendations to optimize the management and operation of the GKIP, ensuring sustainable and equitable benefits for all stakeholders. The valuation studies targeting impact evaluation might be helpful to derive precise information if the following framework is to be employed in the future studies. Impact evaluation studies focus on the theory of change of a specific treatment. Here treatment groups are beneficiaries of GKIP and associated benefits e.g., non-material NPC and regulating NPC received by beneficiaries will be appropriate indicators to see the change between treatment groups and control groups.

METHODOLOGY

Study Area Description

The Ganges-Kobadak irrigation project (GKIP) is the largest surface water irrigation scheme in Bangladesh (see Figure 2) which started operation since the 1960s (IMED, 2014). The GKIP utilizes an irrigation system where water is pumped from the Ganges River and is distributed through gravity-fed canals. While flood control and drainage improvement are minor components of the system, the primary objectives of the project include increasing food production, enhancing cropping patterns, raising cropping intensity, and improving the socioeconomic conditions of the farmers. The project serves the southwestern part of Bangladesh, irrigating approximately 142000 hectares of land through a 971-kilometer canal network that spans thirteen thanas across four southwestern districts. Table 2 depicts a brief overview the project. The GKIP has the potential to act as the food-grain and vegetable basket of Bangladesh, fulfilling a critical role in ensuring agricultural productivity and food security.

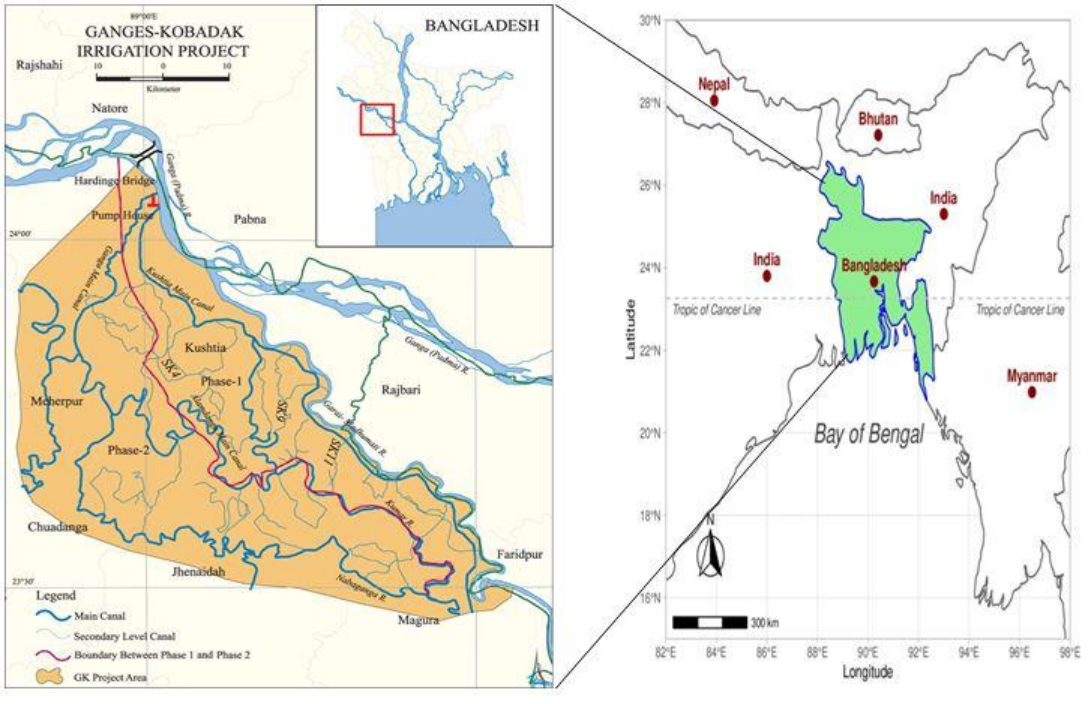
TABLE 2. GKIP- A BRIEF DESCRIPTION

Project area (gross, in 1954)	197,500 ha
Project area (gross, in 2013)	197,000 ha
District	4 Nos. (Kushtia, Chuadanga, Jhenidah, Magura)
Upazila/Thana	13 Nos. (Kushtia, Kumarkhali, Khoksha, Mirpur, Bheramara, Daulatpur, Alamdanga, Chuadanga, Harinakundu, Jhenidah, Sailkupa, Magura and Sreepur)
Population (in 1954)	20 lakh
Population (in 2011)	42 lakh
Irrigable land (in 1954)	1,42,000 ha
Project implementation period	1st Phase: 1955-56 to 1969-70 2nd Phase: 1960-61 to 1982-83 URP: July 2000 – June 2009

Project implementation cost	Tk. 739 million
First irrigation supply 2535-+533c	1962
Pump house (main + auxiliary)	2
Total discharge capacity (avg.)	85 cumec (1000 cusec per pump)
Efficiency of the new pumps	60 - 65% (in dry season), 78% (flood/rainy season)
Flood control embankment	39 km
Irrigation canal	a) Main irrigation canal (3 nos.) 193 km b) Secondary canal (49 nos.) 467 km c) Tertiary canal (444 nos.) 995 km
Drainage canal	971 km
Hydraulic structure	2,184 Nos.
Inspection road	228 km
Project's electricity requirement	14 Mega Watt
Irrigation achievement	in 2013 22,000 ha (boro) 42,742 ha (aus) 96,000 ha (aman)
	in 2014 26,000 ha (boro)
Annual operation cost	Tk. 290 million
Water user association formed	324 nos.
Total outlets	3,500 nos.

Source: IMED, 2014

FIGURE 2. CATCHMENT AREA OF GK IRRIGATION PROJECT



Source: Authors' Compilation Based on Banglapedia.org and Hossain et al. 2020

Data and Methods

This study employed a descriptive research design utilizing a cross-sectional household survey to assess the impacts of the Ganges-Kobadak Irrigation Project (GKIP) on catchment-area households. Primary data were collected from 180 households in GKIP beneficiary communities across the Kushtia district. Due to logistical constraints and the exploratory nature of the study, a convenience sampling method was used to facilitate rapid data collection from readily accessible respondents. While this approach limits the generalizability of the findings, it offers valuable preliminary insights to guide future large-scale research. Data were gathered through a structured questionnaire consisting of both closed-ended items (e.g., Likert scales, multiple-choice questions) and open-ended sections for qualitative feedback. The questionnaire addressed four key thematic areas: socio-demographic characteristics, the socio-economic and environmental impacts of GKIP, and nature's contributions to people (NCP). The surveys were administered over a three-week fieldwork period conducted between March and April 2025.

RESULTS AND DISCUSSIONS

Socio-Demographic Profile

Socio-demographic characteristics play a catalytic role in revealing the perceived impact of GKIP on society, economy and environment. Table 3 shows the demographic profile of the 180 respondents where majority were found to have male (71.7%), with females comprising 28.3% of the sample. Most participants were between the ages of 31 and 45 (37.8%), followed by those aged 46–60 (30.6%). Younger respondents under 30 made up 20.6%, while those above 60 accounted for 11.1%. In terms of occupation, farming was the most common (36.7%), followed by labor (26.1%), housewives (16.1%), shopkeepers or self-employed individuals (15%), and fishing (6.1%). Household sizes tended to be larger, with 43.9% living in households of more than six members, 34.4% in households of 4–6 members, and 21.7% in smaller households of 1–3 members. Educationally, a significant portion had no formal education (29.4%), while others had achieved primary (21.1%), secondary (23.9%), and higher secondary (25.6%) levels of schooling, indicating a moderately educated population with a notable proportion lacking basic education.

TABLE 3. SOCIO-DEMOGRAPHIC PROFILE OF HOUSEHOLDS

Characteristics/ variable	Categories	Frequency (n=180)	Percentage (%)
Gender	Male	129	71.7
	Female	51	28.3
Age range	Less than 30	37	20.6
	31-45	68	37.8

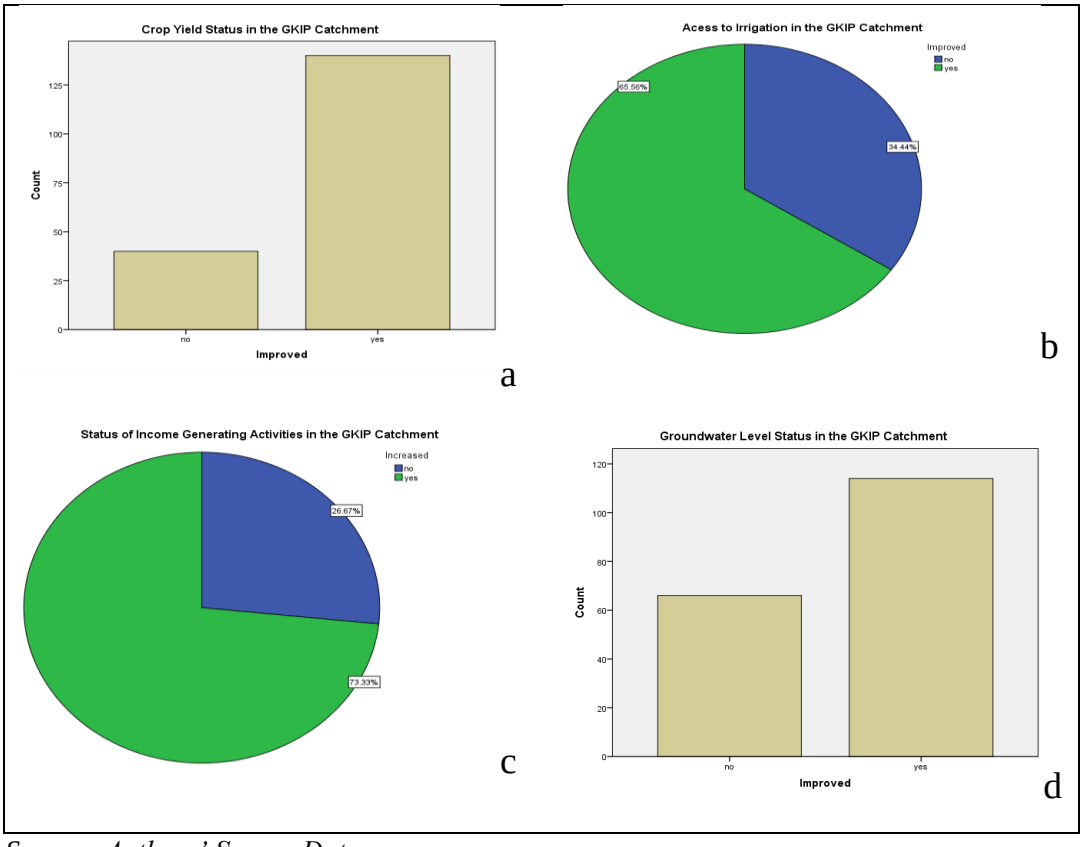
	46-60	55	30.6
	60 to above	20	11.1
Occupation	Farming	66	36.7
	Laborer	47	26.1
	Shopkeeper/self employed	27	15.0
	Housewife	29	16.1
	Fishing	11	6.1
Households size	1-3 persons	39	21.7
	4-6 persons	62	34.4
	Above 6 persons	79	43.9
Education	No formal education	53	29.4
	Primary	38	21.1
	Secondary	43	23.9
	Higher secondary	46	25.6

Source: Authors' Survey Data

Socio-Economic and Ecological Impact of GKIP

The Ganges-Kobadak Irrigation Project (GKIP) has an impact on the lives and environment of the local population. Charts show that 77.8% of respondents reported an improvement in crop yield within the GKIP catchment area, while 22.2% did not observe any change, indicating a generally positive impact of the project on agricultural productivity. Similarly, majority of the respondents (65.6%) experienced improved access to irrigation as a result of the GKIP, while 34.4% reported no improvement. This indicates that the project has had a significant positive impact on water availability for agricultural use, contributing to better crop management and productivity for the majority of the population in the catchment area. Respondents were asked to whether GKIP induces the income-generating activities of the local people, chart (c) in figure 3 shows that 73.3% of respondents reported an increase in income-generating activities following the implementation of the GKIP, while 26.7% did not observe any improvement. This suggests that the project has positively contributed to enhancing economic opportunities and livelihood diversification for the majority of households in the catchment area.

FIGURE 3. SOCIO-ECONOMIC AND ECOLOGICAL IMPACT OF GKIP



Source: Authors' Survey Data

Respondents were also asked about the contribution of GKIP on the society, economy and environment in the catchment area. The responses reveal diverse community perceptions regarding the importance of nature's contributions across material, regulating, and non-material dimensions. Table 4 comprises the survey results of the respondents' perceived contribution of GKIP on society, economy and environment aligning the items of NCP. The table revealed that GKIP beneficiaries prioritize material and non-material contributions to people (NPC), with Rural Connectivity (27.8% rating it extremely important) and Agro Biodiversity (25% extremely important) perceived as most critical, reflecting their direct impact on livelihoods and agricultural sustainability. Conversely, Pest & Disease Regulation (48.9% not at all important) and Habitat Creation (22.8% not at all important) were undervalued, suggesting limited awareness of ecological regulating services. Mixed perceptions emerged for Food Production (21.1% extremely important vs. 14.4% not important) and Climate Regulation (18.9% extremely important vs. 20.6% not important), highlighting uneven experiences or recognition of benefits. Moderate emphasis was placed on Soil Fertility (23.9% extremely important) and Landscape Aesthetic (22.2% extremely

important), underscoring agrarian reliance and cultural value. These findings underscore the need to integrate community priorities—such as health (21.1% extremely important) and infrastructure—into policy while addressing knowledge gaps in ecological services to enhance GKIP's sustainability and equity.

TABLE 4 HOUSEHOLD'S PERCEIVED IMPACT OF GKIP (*NATURE CONTRIBUTION TO PEOPLE*)

NPC Items ***(n=180)***	**Not at all Important**	**Slightly Important**	**Moderately Important**	**Very Important**	**Extremely Important**
Food Production (material NPC)	26(14.4%)	46(25.6%)	41(22.8%)	29(16.1%)	38(21.1)
Soil Fertility (regulating NPC)	33(18.3%)	31(17.2)	33(18.3%)	40(22.2%)	43(23.9%)
Habitat Creation(regulating NPC)	41(22.8%)	43(23.9)	30(16.7%)	37(20.6%)	29(16.1%)
Erosion Regulation(regulating NPC)	36(20.0%)	45(25.0%)	36(20.0%)	29(16.1%)	34(18.9%)
Soils Remediation Capacity (regulate NPC)	42(23.3%)	39(21.7%)	28(15.6%)	37(20.6%)	34(18.9%)
Agro Biodiversity(regulating NPC)	31(17.2%)	29(16.1%)	30(16.7%)	45(25.0%)	45(25.0%)
Landscape Aesthetic (non-material NPC)	31(17.2%)	39(21.7%)	38(21.1%)	32(17.8%)	40(22.2%)
Climate Regulation (regulating NPC)	37(20.6%)	30(16.7%)	37(23.3%)	42(20.6%)	34(18.9%)
Pest & Disease Regulation (regulating NPC)	88(48.9%)	44(24.4%)	22(12.2%)	17(9.4%)	9(5.0%)
Rural Connectivity (non-material NPC)	16(8.9%)	31(17.2%)	38(21.1%)	45(25.0%)	50(27.8%)
Education (non-material NPC)	37(20.6%)	41(22.8%)	33(18.3%)	35(19.4%)	34(18.9%)
Health (non-material NPC)	35(19.4%)	36(20.0%)	31(17.2%)	40(22.2%)	38(21.1%)
Households Use (non-material NPC)	34(18.9%)	35(19.4%)	41(22.8%)	32(17.8%)	38(21.1%)
Fish Production (material NPC)	43(23.9%)	31(17.2%)	33(18.3%)	40(22.2%)	33(18.3%)

Source: Authors' Survey Data

CONCLUSIONS AND FUTURE RESEARCH DIRECTION

The Ganges-Kobadak (GK) irrigation scheme is instrumental in enhancing agricultural productivity, socioeconomic conditions, and environmental sustainability in Bangladesh. Despite the criticisms and methodological shortcomings identified in this impact evaluation, the project has demonstrated significant benefits. Employment opportunities have notably increased in various sectors, including agro-industry and fish production, leading to improved household incomes and living standards. The project's influence extends to education and healthcare, contributing to the overall well-being and social prestige of the community. From an environmental perspective, the GK irrigation scheme supports Sustainable Development Goal 15 by fostering biodiversity. The development of rich forest biodiversity along the canals and the use of these areas as rural roads highlight the project's multifaceted benefits. The evolving flora and fauna within the scheme area signify the positive environmental impact and potential for long-term ecological sustainability. However, the evaluation of the GK system would benefit from more rigorous methodologies, including nonmarket valuation and standard impact evaluation techniques, to capture the full spectrum of economic, social, and environmental impacts accurately. Addressing these methodological gaps will provide a more comprehensive and reliable assessment of the project's outcomes, ensuring that its benefits can be maximized and its drawbacks mitigated. The GK irrigation scheme exemplifies the potential of large-scale irrigation projects to contribute to sustainable development by balancing agricultural needs, socioeconomic growth, and environmental conservation.

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