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SUSTAINABLE IRRIGATION DEVELOPMENT: KNOWLEDGE GENERATION FOR KARNALI-MOHANA RIVER BASIN

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ABSTRACT

Water resources planning and management requires technical knowledge as well as social and environmental considerations and enabling environment for sustainable and equitable development. In this context, this paper highlights the Digo Jal Bikas project which is using a multi-disciplinary framework to generate science-based understanding required for sustainable irrigation development. The project is creating a knowledgebase including an inventory of irrigation and hydropower projects; water availability under current and future climatic conditions; environmental flows requirements for various types of river systems; trade-off analysis of various water resources development scenarios; and water governance analysis. We present here how the project is generating such a multi-disciplinary knowledgebase that is key for promoting sustainable irrigation development in the Karnali-Mohana basin in the western Nepal.

Keywords*: Irrigation; Karnali; Knowledgebase; Mohana; Sustainability*

1. INTRODUCTION

Nepal remains one of the poorest countries in South Asia with 23.8% of the population living below the poverty line. Despite increase in access to improved drinking water and sanitation (UNDP, 2013), water resources identified as key for unleashing the economic prosperity of Nepal (WECS, 2011), remains an under-developed sector. The water resources availability in the country is 225 billion cubic meters (BCM) per annum. Yet, only an estimated 15 BCM (less than 7%) has been utilized for economic and social purposes (WECS, 2005) and only 24% of arable land is irrigated. The large potential for the development of groundwater resources in the Terai for irrigation remains untapped. Crop productivity is significantly lower than the rest of South Asia (Bartlett et al., 2010) and the country relies heavily on food imports. The aforementioned statistics reveal that water resources development, particularly to aid hydropower and agricultural sectors, is expected to continue at a faster rate than before. However, there are many challenges to ensure sustainable water resources development while allocating water to competing uses such as securing food without compromising water and energy security.

Data/information availability, particularly for western part of Nepal, is sparse. Therefore, it is a critical first step to develop a scientific knowledge and evidence base supported by adequate assessment tools to support decision-making in water management. Due to the inherent complexity of water resources systems, and existing biophysical and geographical diversity of the Nepalese rivers, data and watershed models are especially vital to dispel misconceptions about the potential impacts of water resources development on the often conflicting water use sectors and stakeholders (Sadoff et al., 2013). In addition to technical knowledge, social and environmental considerations, and enabling environment are also required. Only an improved knowledgebase and sound tools can help understand the implications of water resources development and prioritize sustainability and equity among existing livelihoods and ecosystem in decision-making.

In this context, International Water Management Institute (IWMI) has taken the initiative of knowledge generation for water futures of western Nepal under the project "Digo Jal Bikas (DJB)" with funding support from United States Agency for International Development (USAID). The DJB project has the goal of promoting sustainable water resources development in western Nepal by balancing economic growth, social justice, and sustenance of healthy/resilient ecosystems. One of the milestones in achieving this goal is the development of a multi-disciplinary knowledgebase. This paper highlights the approaches used and results obtained so far to develop sound knowledgebase pertinent to sustainable water development in the western Nepal, with focus on irrigation development in the Karnali-Mohana (KarMo) river basin.

2. SUSTAINABLE IRRIGATION DEVELOPMENT

"Sustainable development" was coined in 1987 in the report "Our Common Future" by the Bruntland Commission, in their effort to link economic development and environmental stability. The report defines sustainable development as "the development that meets the needs of the present without compromising the ability of future generations to meet their own need". Likewise, sustainable irrigation water management should be able to achieve two objectives simultaneously: sustaining irrigated agriculture for food security and preserving the associated natural environment (Cai et al., 2001).

Sustainable irrigation system is designed to work throughout its lifetime with positive implications to social livelihood, environment, and economy. Sustainable irrigation can be characterized by various indicators such as system reliability, reversibility and vulnerability of water supply system; integrity of environmental system; equity in water sharing; and economic profitability. Sustainable irrigation requires knowledge and understanding of various aspects such as

- Water availability: how much water is available in a year and how it is distributed over seasons and location within the watershed? How is the water availability and its distribution expected to change in the future under both climatic and non-climatic changes?
- Irrigation water demand: How much is the current and projected future demand? How are they distributed now and expected to be distributed in the future across space and time?
- Trade-off analysis: What are trade-offs in water allocations across various water users as well as other aspects of irrigation system development and management?
- Environmental flows (E-flows): How much water is required to satisfy the environmental needs (i.e., environmental flow requirements)?

- Water governance/management: What is the current condition of water governance (policies, institutions, public participation, capacity building, etc.)? How can the water governance mechanism be improved and effective?

3. DIGO JAL BIKAS PROJECT

The Digo Jal Bikas (DJB) project was designed to address the need of improved knowledgebase and tools to help understand the implications of water resources development for the sustainability and equity of existing livelihoods and ecosystem to improve decision-making. The project aims to contribute in achieving the goal of promoting sustainable water resources development in western Nepal by means of addressing following three objectives: i) construction of sound knowledgebase; ii) development and application of tools, models and approaches; and iii) formulation of integrated policy and management guidelines. The 3-year project (April 2016 – March 2019) is focuses on Karnali-Mohana and Mahakali basins in western Nepal. It adopts a two-tier approach: analysing water resources availability under current and future conditions by linking hydrological and economic realities in a hydro-economic modelling at basin level to develop knowledgebase for policy and planning purpose; and analysing water-governance mechanisms and characterize constraining and facilitating factors at local level. The project is structured under eight work packages (WPs); six core and two supporting WPs (Figure 1).

The DJB project recognizes that planning of water resources management considering sustainable and equitable development cannot limit itself to static biophysical analysis. Institutions, socio-economic constraints and opportunities, particularly gender and caste relations, power dynamics and geo-political realities shape the impact of water management at basin/sub-basin and national/local scales. Future challenges and opportunities linked to climate change, economic globalisation, and political transitions also need to be considered. At a basin level, transboundary issues can further complicate resource management. Similarly, at the local level, increasingly fragmented landholdings, skewed land distribution and exploitative resource-use tenure relations have reduced the incentives or capacities for farmers to invest in technologies that improve agricultural productivity. Therefore, the DJB project includes various technical, socio-economic, environmental and governance analysis such as hydrological modelling, hydro-economic modelling, environmental flow assessment, future scenario development, water governance analysis, and gender analysis to support sustainable water resources development. In particular, developing a holistic knowledgebase to support sustainable irrigation is key as agriculture is one of the biggest water user as well as employer in Nepal.

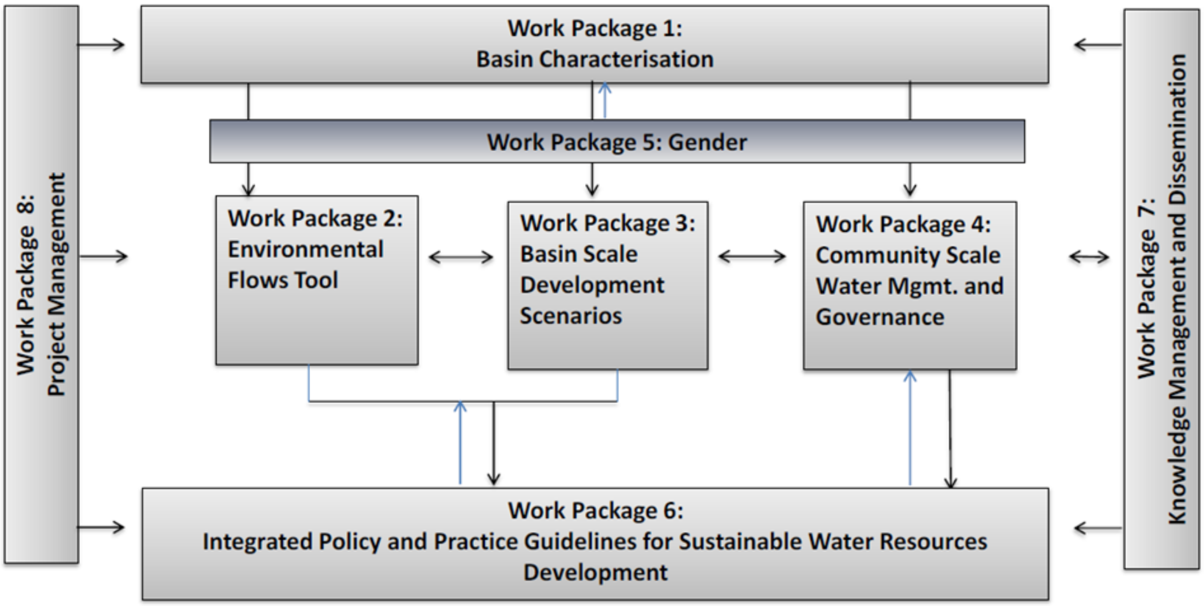

Figure 1: Structuring of the DJB project under eight work packages (WPs)

4. CURRENT KNOWLEDGE GENERATION EFFORTS

To efficiently develop a multi-disciplinary knowledge base, IWMI is running multiple strategies in parallel under the various WPs in the DJB project. IWMI is compiling relevant data from secondary sources and literature where available. Research activities are underway to fill identified knowledge gaps through primary data collection, watershed modelling and use of other analysis tools and frameworks.

4.1 WATER RESOURCES AVAILABILITY UNDER CURRENT AND FUTURE CONDITIONS

Hydrological modelling using Soil and Water Assessment Tool (SWAT) is underway to simulate hydrological condition and assess water resources availability under current and future conditions. Bio-physical data required as input to the SWAT model were gathered from national sources first and from international sources where national datasets did not exist.

The Karnali-Mohana (KarMo) basin is delineated above the Nepal-India border and covers an area of 49,889 km^2. About 6.9% of the KarMo basin lies in India. The basin has been discretized into 111 sub-basins, which covers major tributaries of Karnali as well as Mohana. The sub-basins and spatial distribution of other input parameters such as land use/cover, soil, topography, and hydro-meteorological stations are shown in Figure 2.

Precipitation data from 36 stations, temperature and humidity data from 22 stations, sunshine hours data from 5 stations, and wind speed data from 7 stations are used as input to the model. There are 21 soil types in KarMo basin. The most dominant soil is the Gelic Leptosols (LPi) that covers nearly 34.2% of the KarMo basin. It is followed by Eutric Regosols (RGe, 20.5%), Humic Cambisols (CMu, 14.2%), Eutric Cambisols (CMe, 11.8%) and others. In terms of land use/cover, forest cover is the most-dominant LULC type, which covers more than one-third of the basin area. It is followed by grassland, barren land, snow/glacier covers, and rain-fed agriculture. Nine hydrological stations have been selected for model calibration and validation which are currently underway. After satisfactory model performance is achieved, the SWAT model outputs will be used to estimate the water balance and availability under current and future scenarios.

4.2 INVENTO]Y OF IRRIGATION SYSTEMS

We collected data from primary and secondary sources such as website of Irrigation and Water Resources Management Project (IWRMP) under the Department of Irrigation (DOI-IWRMP) (accessed on 2 March, 2017); personal correspondence with officials from DOI-IWRMP; and report related to the development of database for irrigation development in Nepal (2014). Then we synthesized available information and finalized key attributes as following: i) project name; ii) location (latitude, longitude, address, district); iii) gross command area (GCA); iv) net command area (NCA); v) design discharge (liters per second); vi) type of source (surface water or groundwater); vii) status (completed, under construction, and planned); and viii) date of completion.

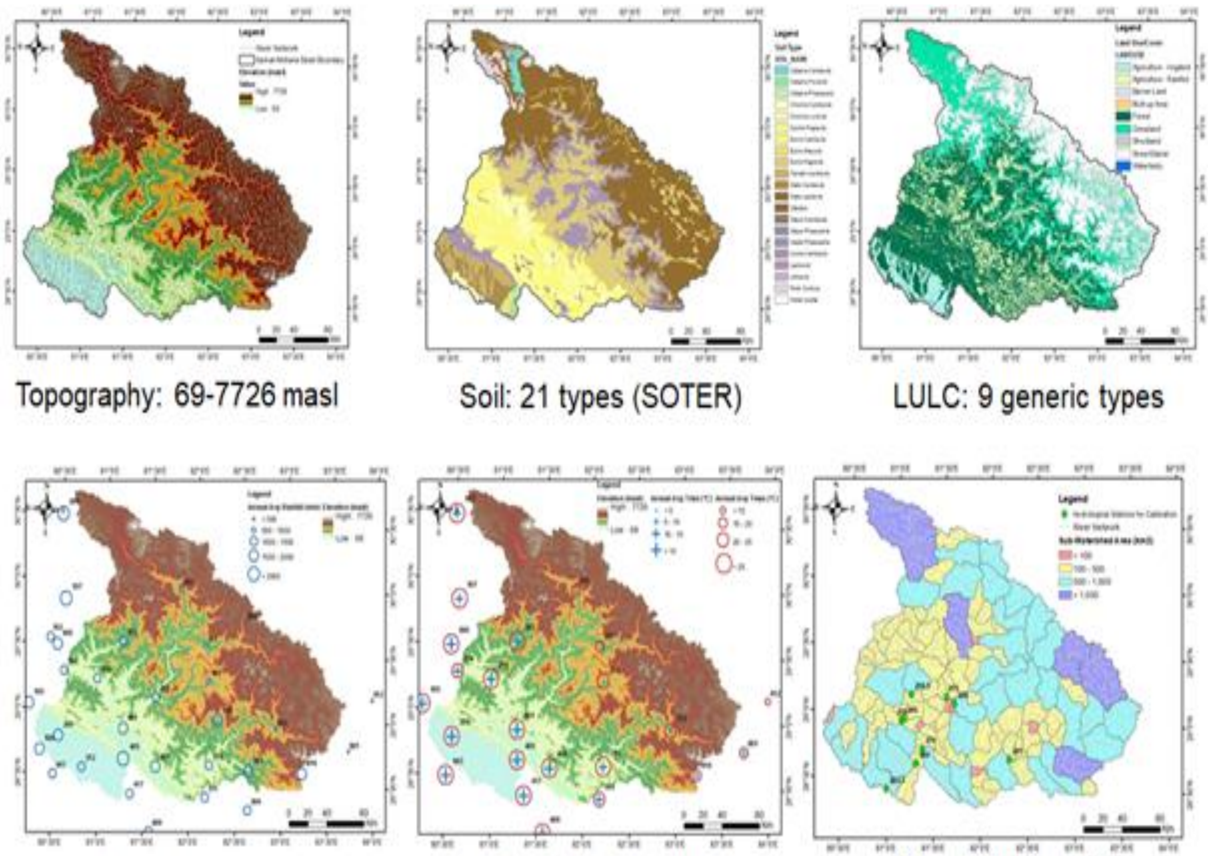

Figure 2: Spatial distribution of input parameters and sub-basins within Karnali-Mohana basin (*Data source: Land use/cover (LULC) data from ICIMOD (2010) for Nepal and ESA-LCCI (2016) for outside Nepal; Soil types from Soil and Terrain Database Program (SOTER); Topography from ASTER GDEM version-2 (30m resolution)*)

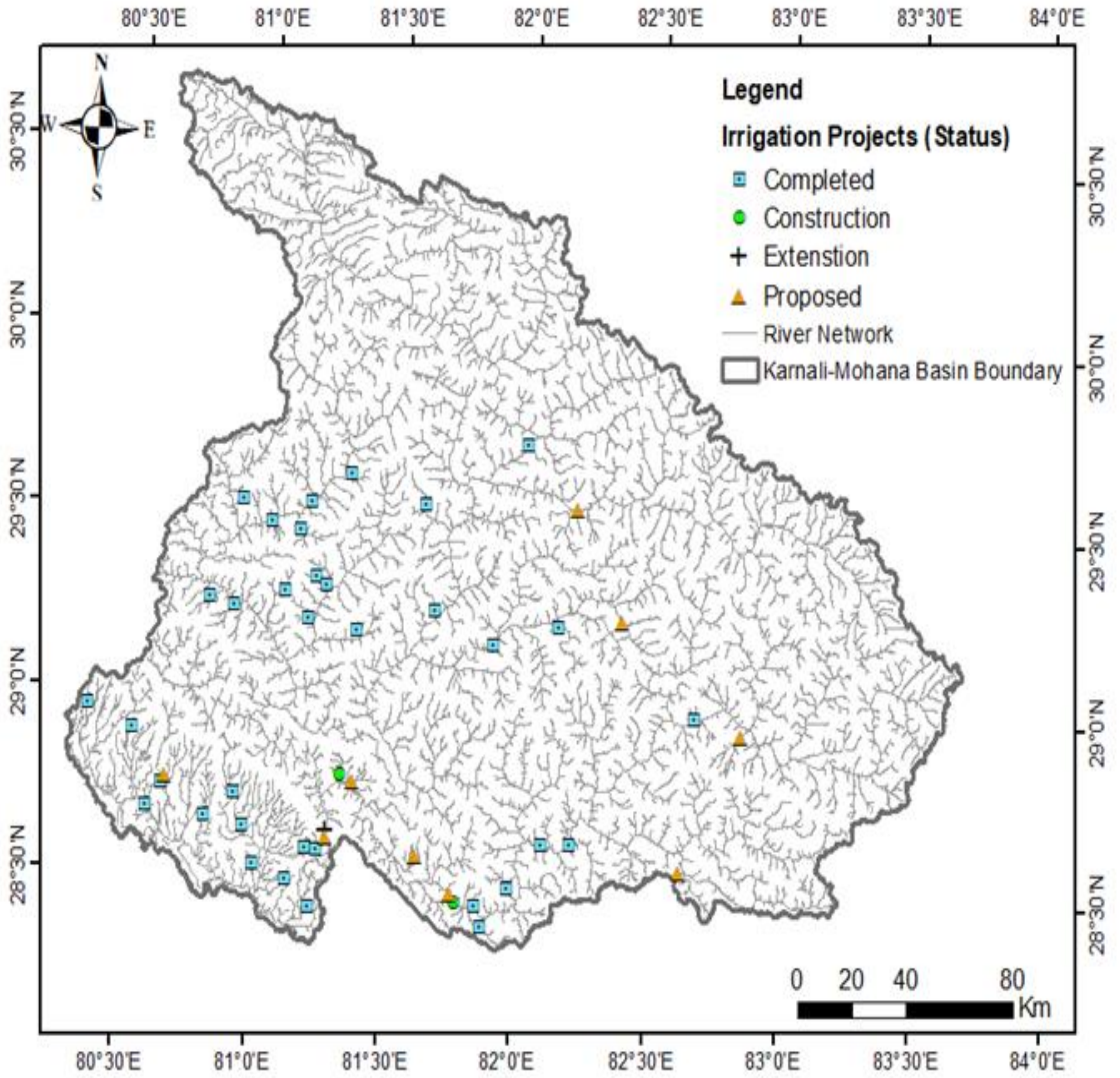

Figure 3: Status of identified irrigation projects with NCA>100 ha in Karnali-Mohana basin.
A total of 48 irrigation projects with NCA of 100 ha or larger were identified and are listed in Table 1. Their location according to type and distribution of net command area are shown in Figures 2 and 3, respectively. The total NCA of the identified projects is 209, 322 ha, which vary from 100 – 98, 026 ha for various projects. It consists of 36 completed projects (NCA = 33,029 ha), 3 under construction/extension projects (NCA = 71,700 ha), and 9 proposed projects (NCA = 104,593 ha). Three under construction projects are Ghat Gaun in Surkhet, Bheri Babai Diversion and Rani Jamara Kuleria. A similar inventory for hydropower projects have also been developed under DJB.

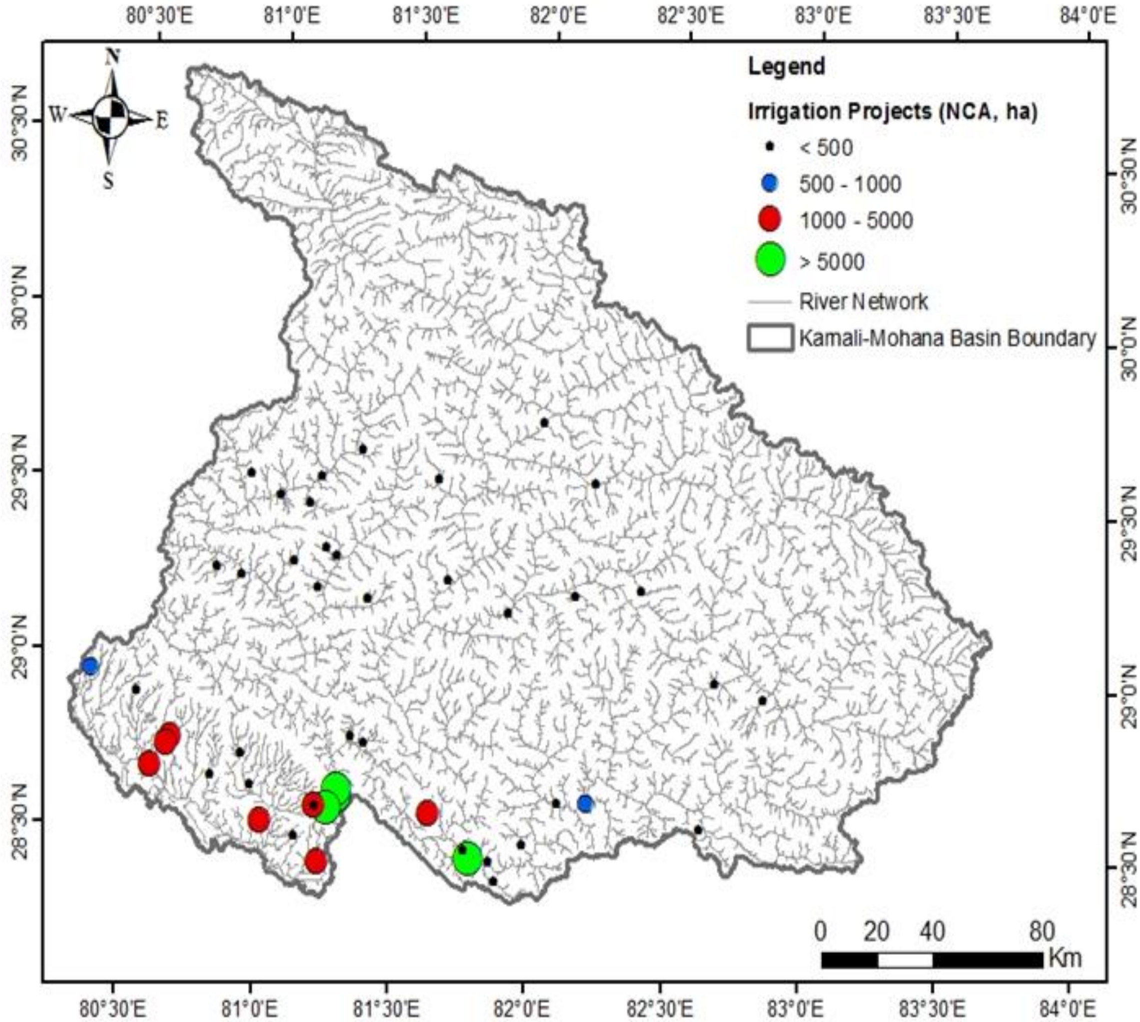

Figure 4: Spatial distribution of net command area of identified irrigation projects with NCA>100 ha in Karnali-Mohana basin

4.3 ENVIRONMENTAL FLOWS (E-FLOWS) ASSESSMENT

Certain amount of water should be released from in-stream water infrastructures to main riverine ecosystems downstream. This release requirement to sustain the environment is referred to as environmental flows or e-flows. The modern definition of e-flow includes not only the quantity of water required, but also the timing and quality of water required to sustain freshwater ecosystems which can also support human livelihoods. There are various approaches for e-flow assessment, including the traditional approach commonly used in Nepal were e-flow requirement is taken as 10% of mean monthly flow of the driest month. To provide a stronger scientific and localized basis for E-flows, primary data collection is being done under DJB. We are taking samples of aquatic macro invertebrates from the project area over the year. Three seasons of sampling have been completed at various locations identified using various stratification criteria. Laboratory analysis of the samples are underway. Outputs of the macro invertebrate sampling will be used to modify IWMI's hydrology-based E-flows calculator to incorporate ecological criteria.

Table 1: Attributes of irrigation projects in Karnali-Mohana (KarMo) basin shown in Figure 3.

ID	Name	Location	District	LAT	LON	GCA_ha	NCA_ha	Q_lps	Basin	Status	Completion
1	Khatijyula	Laha	Dolpa	28.994	82.667		100		Karnali	Completed	8/6/2010
2	Maspatal	Jair-1-7	Humla	29.721	82.003		100		Karnali	Completed	-
3	Ghunkhaya	Ranchuli-8,9	Kalikot	29.169	81.890		104		Karnali	Completed	2/28/2012
4	Giri Khola	Haku-1-9	Jumla	29.226	82.140		110		Karnali	Completed	-
5	Bhurchaur	Bhur-7,8	Jajarkot	28.630	82.096	130	120		Bheri	Completed	-
6	Latamandu	Latamandu	Doti	29.263	80.808	150	120		Karnali	Completed	6/16/1905
7	Rithapata Subedi	Rithapata, Subeda	Bajhang	29.536	81.181	156	125		Karnali	Completed	6/11/1905
8	Khapdad	Khaptad	Achham	29.331	81.208	175	140		Karnali	Completed	6/16/1905
9	Su Tar	Sutar	Achham	29.191	81.371	175	140		Karnali	Completed	6/16/1905
10	Lungreli Prbeli	Lungra	Achham	29.219	81.185	176	141		Karnali	Completed	6/16/1905
11	Kalapatthareswar	Mudhe Gaun 1-9	Doti	29.244	80.903	170	150	256	Karnali	Completed	-
12	Khatikulo	Phukot	Kalikot	29.258	81.663		150		Karnali	Completed	2/28/2012
13	Kolti	Kolti	Bajura	29.546	81.619	188	150		Karnali	Completed	6/16/1905
14	Pikhet	Kotbhairav	Bajhang	29.478	81.034	194	155		Karnali	Completed	6/16/1905
15	Thapa Gaon	Bhamchaur-7	Bajhang	29.536	80.923	194	155		Karnali	Completed	6/16/1905
16	Majhi Gaon	Majhigaun	Bajhang	29.456	81.144	213	170		Karnali	Completed	6/11/1905
17	Talkot Dantoli	Dantola	Bajhang	29.617	81.330	215	172		Karnali	Completed	6/16/1905
18	Kadamandu	Kadamandaun 4-9	Doti	29.291	81.092	233	200	410	Karnali	Completed	6/16/1905

ID	Name	Location	District	LAT	LON	GCA_ha	NCA_ha	Q_lps	Basin	Status	Completion
19	Amarawati	Pathraiya- 8, 9	Kailali	28.590	81.203		200		Karnali	Completed	-
20	Udasipur STW	Udasipur- 2, 5	Kailali	28.665	80.815		200		Mohana	Completed	-
21	Malarani Sahare	Malarani 7,9/Sahare 4,5	Surkhet	28.396	81.876	212	200	450	Bheri	Completed	-
22	Bandegada	Godawari	Kailali	28.892	80.531		205		Mohana	Completed	-
23	Kharkhola	Gumi	Surkhet	28.455	81.852		225		Bheri	Completed	7/1/2010
24	Sadhepani DTW	Ghodaghori Na.Pa.-7,8	Kailali	28.642	80.960		240		Mohana	Completed	-
25	Babla	Babala	Achham	29.309	81.249	312	250		Karnali	Completed	6/16/1905
26	Kaprichour	Kaprichaur	Surkhet	28.505	81.975	321	257		Karnali	Completed	6/13/1905
27	Ratipur	Tikapur	Kailali	28.502	81.134		367			Completed	-
28	Gaidakheda	Ramshikharjhala	Kailali	28.732	80.927		450		Mohana	Completed	-
29	Chaurjahari	Bijayshwari	Rukum	28.633	82.207	750	600		Karnali	Completed	5/31/1905
30	Kalapani	Jhalari	Kanchanpur	28.950	80.360	630	600	1200	Mahakali	Completed	-
31	Khutia Phase-I	Beladevipur	Kailali	28.746	80.650	1875	1500		Karnali	Completed	6/9/1905
32	Banikulo	Joshipur-2, 5, Thapapur- 1-9	Kailali	28.539	81.006		1800		Mohana	Completed	6/1/2016
33	Surya patuwa		Bardiya	28.429	81.223		2000		Karnali	Completed	-
34	Pathraiya	Pathariya	Kailali	28.590	81.202	2700	2133		Karnali	Completed	5/27/1905
35	Mohana	Dhangadi	Kailali	28.680	80.591	5670	3500		Karnali	Completed	6/9/1905

ID	Name	Location	District	LAT	LON	GCA_ha	NCA_ha	Q_lps	Basin	Status	Completion
36	Rajapur		Kailali	28.588	81.249		15800			Completed	-
37	Garjyangkot			29.252	82.382		200		Karnali	Prioritized in Basin MP	-
38	Koreilli Khola Lift			28.482	81.761		316		Bheri	Prioritized in Basin MP	-
39	Surkhet Valley			28.582	81.625		2700		Bheri	Prioritized in Basin MP	-
40	Chila			28.953	82.846		110		Bheri	Proposed	-
41	Dhilamaghatta			29.552	82.198		141		Karnali	Proposed	-
42	Rukumkot			28.573	82.621		275		Bheri	Proposed	-
43	Babiyachaur			28.779	81.375		325		Bheri	Proposed	-
44	Khutiya-II		Kailali	28.766	80.662		2500		Mohana	Proposed	-
45	Karnali Chisapani		Bardiya, Kailali	28.624	81.283		98026		Karnali	Proposed	-
46	Ghat Gaun	Ghatgaun	Surkhet	28.794	81.328		400		Bheri	Under Construction	-
47	Bheri Babai Diversion		26 VDCs in Surkhet and Salyan (Bheri Corridor) Bardiya and Banke (Babai Side)	28.460	81.777		51000	40000	Bheri	Under Construction	-
48	Rani Jamara Kuleria		Kailali	28.642	81.281		20300	100000	Karnali, Mohana	Under Extension	-

***Notes**: Groundwater-based irrigation systems are highlighted in the table. STW is shallow tubewell; DTW is deep tubewell.*

4.4 WATER GOVERNANCE/MANAGEMENT

Three pilot sites (1 in Kailali and 2 in Doti) are selected and detailed socio-economic baseline survey is completed including over 600 households. The data analysis is underway. At the end of the analysis, we are expecting to understand policy and institutional landscape in the basin; challenges/opportunity in the existing landscape and their implications in water governance; availability and functionality of local water institutions; and potential entry points for change in governance for sustainable water resources management.

4.5 TRADE-OFF ANALYSIS

Water resources management in a country like Nepal looking to capitalize on its abundant water resource for development requires considerations for water allocation across multiple sectors. The trade off between winners and losers in any development scenario needs to be understood to select development pathways that is equitable and maximize the benefit of all stakeholders. To this end, we aim to use a hydro-economic model to simulate develop a range of possible future scenario related to water resources development, and then analyse trade-off across various sectors under each scenario. Such scientific knowledgebase on benefits and costs of various development scenarios will be useful for informed decision-making. Hydro-economic model set-up, data collection from surveys, review of literature and consultation with stakeholders for scenario development are underway.

5. SUMMARY

The DJB is an ongoing project expected to be completed by March 2019. It aims to develop a well-documented inventory of water infrastructures focusing on irrigation projects and hydropower projects; water availability under current and future climatic conditions using hydrological models; environmental flows requirements for various types of river systems; trade-off analysis of various water resources development scenarios using hydro-economic models; and water governance analysis at pilot sites. Learnings from basin-scale (water availability and trade-off analyses) and local-scale (water governance) will then be integrated to develop a policy and practice guidelines for sustainable and equitable use and management of water resources in the Karnali-Mohana basin.

DJB has successfully concluded primary data collection and data pre-processing with on-going preliminary analysis. Based on the collected data, we have already characterized bio-physical setting of the Karnali-Mohana basin. Inventory of irrigation projects is completed. Hydrological model has been setup using compiled data and model calibration is underway. Hydro-economic model set-up and future scenario development are being conducted. Most of the analysis related to water governance (including social, institutional, policy, and gender) has been completed..The data/information presented in this paper and continuously being generated by DJB is expected to be useful for a wide range of stakeholders to understand and implement sustainable irrigation development in the Karnali-Mohana basin.

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