An Area of Dankness: Food Security of Food Producers When the Kosi Comes Down to the Plains

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1 Introduction

The effects of the warming of mountains are expected to spill over to the plains that receive rivers descending from the stressed mountains. Himalayas are warming and, arguably, Himalayan glaciers are receding faster than in other parts of the world (Armstrong, 2010) due to warming. Bihar receives a number of rivers coming down the eastern Himalayas that are known to be warming faster than the western parts of the range. The Kosi Basin (KB) of Bihar in India is a zone below the Himalayas that has always struggled with the consequences of devastating floods. This chapter, based on a field visit, discussions and primary surveys, recounts the features of agriculture in Khagaria, a flood-prone district located in KB and the struggles and adaptations of the rural people in terms of livelihood and agro-practices for their food security.

Although the melting of snow might have been a slow and prolonged process from before the Industrial Revolution (Armstrong, 2010; Oerlemans, 2005), evidences of climate change have created concerns over the warming of Himalayas its receding glaciers (Armstrong, 2010). While research is ongoing and the effect of climate change on India's monsoon is yet to be understood (Vaishnavi, 2019), there are signs of accelerated melting of glaciers especially in eastern Himalayas (Bajracharya et al., 2007; Armstrong, 2010). IPCC reports (2014) suggested that

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Hindukush Himalayas are susceptible to temperature increase by 2 °C in a global warming scenario of 1.5°C by the end of the century. and the glaciers of the region may lose 10–30% of their masses by 2030 (Armstrong, 2010; Gupta, 2023; ToI, 2019) supplemented by the albedo effect. The associated replacement of snow by heavy rains in wetter summers especially in eastern regions of Himalayas (Smith & Bookhagen, 2020) may speed up river flows creating catastrophic floods in the plains.

Consisting of about 16 districts, the KB is over-achingly agrarian with little opportunity for jobs in industry. Agriculture, the main occupation and source of sustenance, is rampantly ravaged by heavy local and upstream rainfall. Floods can arise from varied causes, but in Bihar they are largely due to poor drainage stemming from the limitations of river channels to hold the huge volume of water coming from Himalayan rainfall that even the structural bodies cannot always brook (GoI, 2023). Kosi has a transborder mountainous course. Satellite mapping of the entire valley in multilateral initiatives reveals sharp gradients of terrains, precipitation, temperature and ecology (Wang et al., 2012). While helping in zoning, monitoring and preventing floods, mapping has identified Bihar as the second largest in terms of the number of districts (38) flooded in the last 20 years (GoI, 2023). In the recent 3 years, 2020, 2021 and 2022, floods ravaged 39, 35 and 33 districts, respectively, due to the rise in water levels in Kosi, Bagmati and Ganges and other rivers of North Bihar.

Recurrent Kosi floods, caused by the history of its journey, are a constant pressure on livelihood and food security in KB. The Kosi Basin project, jointly managed by the governments of India, Bihar and Nepal, has limited success as a way of coping with excess water. Incessant rainfall causing an upstream breach in 2008 created disputes as the resulting catastrophic flood raised discourse over engineering as a solution and even over the potential benefit of not having an intervention (Somanathan, 2013). As the reality of floods became accepted, nonstructural means of adaptation such as legislated disaster management (IPCC, 2012; NDMA, 2005), weather prediction, inter-country information sharing, climate change awareness, insurance, flood zoning, wetland conservation and timely relief gained emphasis.

The objectives of this paper are to (1) understand the resource problems created by the flood proneness of farms in terms of land, soil cover and water; (2) existing socioeconomic constraints of the vulnerable population and their adaptation to the challenges by migration, occupation and crop choices; (3) their farming practices guided by ecological and economic constraints along with income potentials of crops and the markets they face; (4) sources of food and role of local agriculture as well as public intervention for their survival; and (5) decisions regarding choice of farming and choices of crops to grow in flood-prone areas by means of econometric regression with economic, natural and policy-induced determinants. This introduction is followed by a background to the area under study and its motivation (Sect. 2), the survey methodology.

2 Background of Study Region and Reason for the Choice

River Kosi is a confluence of three rivers arising from Nepal and Tibet in China. While traversing the Nepal Himalayas, it is recharged by seven tributaries before it crosses the Chhatra gorge to enter India near Bheem Nagar and flow down the plains of North Bihar to join River Ganga near Kursela. Coming a long way of 729 km down the unconsolidated terrains of the Himalayas, it encounters tributaries and severely steep slopes to gather increasingly voluminous loads of water and silts (Li et al., 2020; Kumawat et al., 2020). Sharing a common border with the country Nepal, North Bihar's Himalayan highlands gradually become flat alluvial plains or an 'inland delta', drained by the Ganga, Kosi, Gandak, and Son with their tributaries and other seasonal streams.

Kosi River is typically braided in structure with a migratory behaviour due to intermittent sediment deposition. Bihar itself has an annual rainfall of 1192 mm compared to the 1177 mm of India. Drained by other Himalayas rivers such as Gandak, Mahananda and Ganga, Bihar is rich in water. A densely populated state (Table 1), Bihar has the lowest per capita GDP of Rs. 28,127 at 2011–2012 prices compared to India's Rs. 85110 in 2020–2021. Migration is a major characteristic of Bihar's sociology, and KB in Bihar is a major source of unidirectional and short-term migration to other states (Kumar, 2012; Kumar & Singh, 2018). Although not one of the hotspots of the Green Revolution, Bihar is a rural and agrarian state where the average farm size reduced to 0.39 ha (India 1.08 ha) and net sown area per person to 0.05 ha (India at 0.12 ha) which is cultivated intensely (145% vs. India's 141). Natural calamities keep the whole subregion and its agriculture under threat. Maize, grown also in the summer season (Zayad), is gradually gaining a place in human food habits and food processing activities. As a feedstock of ethanol, maize helps curb global warming.

Earlier a part of the district Munger, Khagaria which became a district in 1981, is preferred for study due to its low-lying location, its proximity to the main Kosi channel and its varied cropping pattern. Kosi hydrology affects districts of Supaul, Madhepura, Saharsa, Madhubani, East Champaran, Sitamarhi and Darbhanga, in the upper levels, and the districts of Begusarai, Katihar, Bhagalpur and Khagaria further downstream. Khagaria is highly prone to floods. With seven community development blocks, its geographical area is 1486 sq. km and its total population is 1.7 million with a sex ratio of 886 per 1000 and a population density of 1122 per sq. km.

At the time of the survey, the urban area of Khagaria covered only 12.46 sq. km area and 5% of the population. Only 58% people were literate and a major chunk of workers (58%) were agricultural laborers. Floods did not spare Khagaria between 2000 and 2010 except in 2006. Because of frequent avulsions, Kosi breaks up into many channels flowing into neighboring districts, but this low-lying district is a leading victim of Kosi hydrology. Embankments are constructed on Kosi and along Ganga in KB but in Khagaria they are built more for Ganga than Kosi.

Table 1 Profile of Bihar agriculture (updated data)

	Population	GDP	Average farm size	Sown land	Rural people	Small farms	Cropping intensity	Agriculture worker	Labor
	Per sq. km	Rs./person	Hectare	Person/hectare	%	(%)	(%)	%Worker	% Agri-worker
Year	2011	2020–2021	2015–2016	2011	2011	2015–2016	2015–2016	2011	2011
Bihar	1102	28,127	0.39	0.05	88.71	96.96	145	73.55	71.83
India	382	85,110	1.08	0.12	64.61	86.08	141	54.60	54.87

Source: DES Website, Census Website, Agriculture Census Website

3 Survey and Method

The study design has to bring out the typical elements of the geographical interest of the region with their subtle variations that differentiate spatial units even under similar riverine conditions. The study location for primary data was determined based on the map of Bihar and its rivers; the listing of districts, blocks and villages; and information on cropping patterns. Meant for understanding the lives of the people and their food insecurity, the area was chosen for its vulnerability to Kosi dynamics. At every stage of sampling, the proximity to the rivers is considered subject to overall geographical commonality.

Of the seven blocks, four blocks, which are closest to Kosi and grow maize, comprise the study region. Villages in each block were divided into two groups based on their distances from the river with the maximum distance at 13 km. One village was selected randomly from each group of villages, making up two villages from each sample block and eight villages from the district. From each village, 15 households were sampled giving representation to 5 different classes of farmers. The multi-stage stratified random sampling coincided with the rabi harvest season of 2015, but the reference year being 2014–15, the survey of 120 farm households covered information from both Kharif and Rabi seasons (Table 2).

Farm classes were specified based on farm size holding but keeping the reality of local land distribution in view, so that they were (i) landless (LL) with no land reported (or actually insignificant land) under the operated farm, (ii) marginal (MG) with farm size up to 1 ha, (iii) small (SM) with farm size above 1 ha but up to 2 ha, (iv) medium (MD) with farm size ranging from 2 to 4 ha and (v) large (LG) with farm size above 4 ha. The sample LL class size is 24; for farming activities, only the 96 landed categories of sample are assessed. Categories medium and large differ from official categorization to capture local reality. The lower limit of the large holding category is taken as 4 ha rather than the official 10-ha cutoff which is scarce in the region. The sample villages were located 4–50 km away from the district headquarters and not more than half a kilometer away from a river. Some villages

Table 2 Sampling for primary survey and crop-growing households in Khagaria district, Bihar

Sample size in each category	No. of households	% Share	No. of crop-growing households	
			Rice	Wheat
Sample Khagaria	120	100	44	83
Block [4 blocks]*	30	25	–	–
Village [8 villages]*	15	12.5	–	–
Landless (LL)**	24	20	–	–
Marginal (MG)**	32	27	14	22
Small (SM)**	21	18	8	20
Medium (MD)**	30	25	16	28
Large (LG)**	13	11	6	13

Notes: *[] figures are number of sampling units. **() are abbreviations

were proximate to multiple rivers and some were accessible to basic facilities only by boat transport. All villages had at least one primary school, an *anganwadi* for early-age children, and medical clinics often, however without trained professionals but secondary education, were available only in some of them.

Socioeconomic, environmental, market and food-related information were asked of households from structured schedules. Prices at which crops were sold (producer price) were collected along with crop yields, acreages, input use and paid-out costs of cultivation as reported by the households. Farmers reported land holding in the local unit of Bigha which was expressed in hectares for analysis using the appropriate conversion rate. The household castes, scheduled caste (SC), schedule tribe (ST) and other backward classes (OBC), as declared officially, were all added up to make the reserved category for this study. Unreserved castes included *Brahmans*, *Bhumihar*, *Rajput's*, *Kayastha*, etc. A migrant is specified as a member who has moved to places beyond the resident district for at least 1 month with or without spouse in the last 2 years, and a migration-exposed household is one which had at least one migrant member. The working age is taken as 15–60 years. Educated members attained high school levels.

A farm is the land possessed for possible cultivation through ownership, patta, or leasing and can be resown too. This land was seen to be actually sown and harvested at least once in the current crop cycle and fully utilized. Land lost, not included in farm size, is the land that became inaccessible to the farmer before sowing. Lost land may have become part of the river or come under wetland protection as a government-regulated public property. Irrigation ratio is that part of the total cropped area, i.e., both single-cropped and multi-cropped areas, of the farm which is irrigated by tanks, government or private canals, tube wells and other wells, sprinklers, drip, etc. Only rice and wheat were specified as the food crops, while the focus of the study was on rice, wheat and maize.

Observations are presented through tables and graphs based mostly on simple averages of data. Returns in monetary value are measured as production value less the paid-out cost for farmers growing that crop. Access to food is measured by earnings or returns from a hectare under that crop in terms of volumes of food.[1] In the

[1] Food Access

$$PHATF_{ij} = (P_j Y_j A_{j-} Cj / P_i$$

Where PHATF is household access to i-th food crop in tonnes per hectare from market, j is crop for sale namely Maize, Rice, Wheat, P_j = producer price of crop j, C_i is paid cost per hectare in Rs. 000 and Yj is yield of the crop j in the farm (Kg/Hectare) and the product in the numerator is the notional returns from crop j if all crop is sold in market without household retention. Food crops rice and wheat which are purchased either from open market at retail price RP or from PDS shop at price PDSP so that Pi = RP or Pi = PDSP. PHATF is a notional access to rice or wheat assuming all product of any of the three crops grown on farm (Tonnes/Hectare) is sold to buy one of the two food crops.

regression.[2] linear model with quadratic (squared variables) and interactions between variables are specified and estimated for the crops to explain their acreages sown using economic, geographic, infrastructure and demographic explanatory variables. Moreover, since any of the three crops, rice, wheat and maize, are not necessarily grown by all sample farmers, a sample selection bias is corrected with Heckman correction[3] (Heckman, 1979). Alongside the quantitative analysis, perception-based responses were also sought both from the sample households and from village communities, traders and authoritative agents. Households reported their sales outlets and also sources of food purchase, the latter mostly consisting of the retail market and public distribution system (PDS). The study team visited three markets in the Khagaria district located at varying distances from the headquarters and nine maize traders to gain ground-level insight to qualify the data gathered. Retail and PDS prices are obtained from the shops.

[2] Regression

$$A_i = a_0 + a_1 X_i + a_2 X_i^{\ 2} + a_3 X_i X_j$$

Where $A_i = f(X)$, A is area under crop I in hectares in sample farm and X comprise explanatory variables.

Explain variables

1. Economic: Relative price, Relative revenue, Access to food (Rice and Wheat), Retail price of food relative to PDS rice, producer price of food relative PDS price, Remittance from migrants.
2. Geographic: Distance from river, ratios of land water logged.
3. Demographic: Share of agriculture workers in household, female share of agriculture workers, share of mignats in workers.
4. Agronomic: Net sown area, irrigated share of area.
5. Infrastructure: Distance from Road, Distant from district/headquarters.

[3] Heckman model

The Heckman selection model assumes that there exists an underlying regression relationship,

$$y_j = x_j \beta + u_{1j} \tag{1}$$

The dependent variable, however, is not always observed. Rather, the dependent variable for observation j is observed if

$$z_j \gamma + u_{2j} > 0 \tag{2}$$

where, $u_1 \sim N(0; \sigma)$, $u_2 \sim N(0; 1)$, $\text{corr}(u_1; u_2) = \rho$

When $\rho = 0$, standard regression techniques applied to the first equation yield biased results. Hackman

provides consistent, asymptotically efficient estimates for all the parameters in such models.

4 Results

Khagaria is full of water bodies including rivers Kosi, Ganga and Bagmati and their channels. Embankments along the river leave enough space for river to flood into but such vulnerable wet areas were also densely inhabited. Surveyed villages had varied positions between the river and embankment, outside the embankment and between two rivers. While interpreting the findings, the riverine specificity of the sample design is kept in mind because the sample is purposively not directed at being representative of the state or even the district but rather to its dank geography. Also, the sample covers households who were primarily cultivators by their own perceptions both in the landed and landless categories. Floods on account of the movement of Kosi River or heavy rainfall in Nepal damaged crops, property communication and roads. Reportedly, at least 52–80% of the area of a sample village was affected, but the early warning was duly given by the district administration and media and victims received public relief.

The adversity of floods came also from sedimentation. A high-level international workshop on 'River Dynamics and Flood Hazard assessment with special reference to the Kosi River' organized on 23 March 2011 in Patna concluded that sedimentation is a bigger problem than water. A mixture of sand and silt, farmers reported that Kosi sediments made the land uncultivable for nearly a decade depending on its thickness. It was unsuitable as a building material too. The sediments also made canal irrigation the Kosi project offered nearly useless though connecting to canals by field channels was also not affordable. Dependence on wells was stronger but digging wells was depleting groundwater. Historically, droughts were also common, most severe in 2001 and reported in the years 2011, 2012, 2013, or 2014. Two villages faced drought in 4 of the previous 5 years and six villages did not report a drought. Migration was common to all villages.

The survey area was infrastructurally poor with weak connectivity. Electricity and telephone (mobile) were available in the villages but not to all households nor for 24 h. Two villages were not electrified at all. Solar plants, distributed by the state government, were not always effective. Not all villages were accessible by paved all-weather roads and even some paved roads became unusable in the monsoon. Bus was not available to all villages and transportation to the nearest town or district headquarters was by modes such as privately hired vehicles and, if distances were short, by big bicycle or rickshaw. Indeed, cultivation seemed to be the major occupation in all the villages surveyed but not the only one. Wage labour outside agriculture; small businesses as the shop owner, vegetable vendors and hawkers; and semiskilled labour such as masons, drivers, cycle repairing and trading were observed livelihoods of the people, but the economic activity might be conducted outside the village. Dairy was a minor occupation but an organized cooperative 'Sudha dairy' was a buyer. Fodder crops are grown on inferior land.

The average household size was fairly large at 7.6 members due to the culture of the joint family (Table 3). With limited fragmentation of land over generations, the culture was also responsible for the large average farm size (Table 4) compared to

Table 3 Societal characteristics and migration tendency of sample households in Khagaria district

	Size	Educated	Female headed	Reserved caste	Migration exposed	Interstate Migrant worker	Labourer	Interstate	Students
Size class	Members per household		% households			% worker		% labour	% migrant
Landless	7.7	1.7	12.5	87.5	70.8	91.4	54.3	89.5	2.9
Marginal	7.0	2.2	12.5	62.5	31.3	100.0	76.5	100.0	10.0
Small	7.5	2.1	4.8	66.7	66.7	75.0	52.4	100.0	9.5
Medium	7.2	2.2	10.0	76.7	40.0	75.0	37.5	100.0	18.5
Large	9.5	1.8	0.0	76.9	69.2	42.9	28.6	100.0	49.3
Sample	7.6	2.0	9.2	73.3	51.7	86.5	53.1	96.1	15.3

Source: Computed from survey data

Note: Reserved castes include SC, ST and OBC (for details see Sect. 3); educated, up to high school; migration exposed, at least one migrant. Secondary data (Census of India, 2011)) from Bihar: SC, 13%; ST, 1.2%; OBC, 68%. Literacy rate is 63%. Female headed, 7.4%; minority religion, 17%

Table 4 Land endowments of sample households in Khagaria district

	Farm size	Cropped area	Intensity of farming	Leased	Irrigated	Land lost
Size class	Hectare		%	% farm size		
Marginal	0.61	0.93	152	32.1	87	0.00
Small	1.52	2.21	145	33.2	87	9.84
Medium	2.77	3.36	121	15.8	86	0.66
Large	5.86	6.07	104	32.1	98	16.25
Sample	2.19	2.66	121	30.7	88	14.61

Source: Computed from survey data
Note: Land lost is not part of farm size

Bihar (0.39 ha). The difference may be attributable to the purposive sample design, definitional differences or even the lack of information on the legitimate use of leased or common land such as river beds, river banks and waterlogged land. The larger average size of a household at 9.5 members in the LG category among all others that have a uniform size between 7 and 8 members cautions against equating economic strength with farm size which was related rather to family cohesion acting as a security in the disaster-prone region with a close-knit support system.

Over half of the sample households were exposed to migration. Men were more likely to migrate for work than women who bore multiple responsibilities. In relatively longer-term migrations, women in charge became the head of household explaining the 9.2% share of female-headed households and a higher share (12%) among LL and MG farm households (Table 3). Among the castes, other backward castes (OBC) were dominant and together with scheduled castes (14.2%) and tribe (8.3%), 73% of respondent households of the sample were in reserved castes, more so in the LL category. Education required for higher salary jobs was lacking.

4.1 Migration

Migration spares no farm size class but not surprisingly, the largest exposure of 71% is observed in the LL category. A sign of regional economic imbalance (much of global migration also occurs also due to distress but which is caused by political unrest), members from severely poor households tend to become periodic migrants. Some of them leave their ties to their roots through women in 'unsettled relationships' resulting in loneliness, hardship and work burden for women (Papademetriou & Martin, 1991). The immensity of the problem of distress-driven migration for the region, migrants, families and society at large is exposed by many incidents (Naregal, 2021).

Households also reported that a high portion (29%) of migrants moved to the National Capital Region (NCR) around Delhi followed by other states in the west such as Punjab, Haryana and Chhattisgarh, while 17%–18% reported intra-state migration within Bihar. Accompaniment of the spouse was confined mostly to

intra-state migration or inter-state migration to the NCR, but remittances per household from the NCR were low due to the higher cost of living compared to migration to the south and to the northeast. A high share of LG households also faced exposure to migration, but a sign of debt and poverty was not conveyed by the smaller share of labourers among their migrant workers (Table 3). Of the migrants, 15% were students and their share were largest at nearly half among the LG, although all categories saw student migration including a 3% share of migrants from the LL. Better access to higher education can also, therefore, explain migration among the LG. Field interactions revealed that students went mostly to Patna or other district colleges in Bihar. Overall, 53% of migrant workers of the sample went as labourers and except in the LL category, all labour migration was inter-state.

4.2 Access to Land

Some cultivable land was leased in and much of the land sown was multi-cropped. Farm size as reported in Table 4 is the sum total of land possessed inclusive of land leased in, while total cropped area incorporates sown land and multiple cropped sown land. Also, farmers reported they did not always have access to their owned land which was lost to them. Asked about the extent and reasons of land loss they suffered during the last 10 years, it could be speculated that another 0.47 ha per household could also have been cultivated over and above the 2.2 ha of farmland reported if land loss could be averted. About 16% of the land was lost according to the farmers.

All classes of households were victims of land loss. The LG suffered the most followed by the MD class. Even the LL households reported having degraded lands lying idle under wetland status though this did not happen among the sample households in this period. The largest land loss came from the river devouring land by its movements (Fig. 1). Sedimentation and waterlogging were also culprits. Human encroachment via canals and highways did not farmland. The embankment was the only intervention that took away land even while floods, whose defence they were, brought losses to most classes.

In a historically feudal state, where leasing was nearly prohibited by law, most households reported its incidence in oral form. Unrecorded agreement between the owner and the user of land not being officially recognized explains the divergence from secondary data. LL and MG farmers sometimes report leasing some insignificant quantum of low-quality land for growing fodder crops. Leasing in of land informally by all classes of farmers meant that subsidies and support went to the landowner rather than the cultivator. The unstructured contracts conveyed a general impression that the lease was usually renewable for 1 year at a time. Both cash rents and produce-sharing arrangements on a 50:50 basis were contracted but sharecropping was more popular than fixed rent. Disputes and even violence were ways of redressing violations of terms.

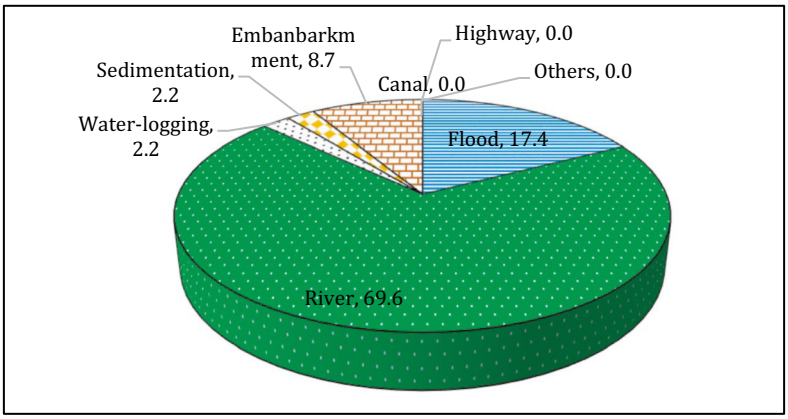

Fig. 1 Factors for land loss in the sample (%)

Table 5 Shares (%) in total cropped area under study crops of all sample households

	Rice	Wheat	Maize	Total
Marginal	21.5	23.7	49.5	94.7
Small	19.9	26.7	44.8	91.4
Medium	23.5	28.9	44.3	96.7
Large	17.8	29.7	50.2	97.7
Sample (Khagaria)	21.1	28.2	47.0	96.3

Source: Computed from survey data
Note: Total cropped area covers the three study crops and other minor crops. Total sample size = 120

Multiple cropping helped expand crop coverage across classes except for the LG class for which farming intensity fell close to one. Interestingly 6% of the landed households also leased out land due to inadequate supervisory power or their interest in off-farm jobs but leasing was not necessarily a localized transaction. Field interactions informed that when poor drainage leading to waterlogging from monsoon rains checked Rabi planting, cropping intensity falling below one was not uncommon. The relation between farm size and intensity of farming clearly seems inverse in this case.

4.3 Farming

Rice, wheat and maize were the major crops making up over 96% of the cropped area in the sample. Others occupied miniscule acreages. The sample households together allocated the largest share (47%) of the total cropped area to maize followed by wheat (28%), while rice the staple food got the least share of 21% (Table 5) and the pattern was similar among the holding classes though not all sample landed

household grew all three crops. The greatest preference to maize in the cropping pattern was shown by LG followed by the MG class. The largest number of farmers in the sample also grew maize (89) followed by wheat (83) and rice (44).

Evidently, not all farmers were privileged with land suitable for staple rice. Farmers seemed reluctant to grow kharif crops for fear of floods. Contrarily, among those 44 (only 37% of the sample) households who chose to grow rice, the average area under rice was large at 1.21 ha, while the mean area under rice of all 96 landed sample households (excluding the LL) was only 0.2 ha revealing the underlying preference for growing rice.

The yield rate of the rice for the 44 rice growers at 1.7 tonnes/hectare was less than in Bihar (1.9 tonnes/hectare) and India (2.4 tonnes/hectare) but that of maize among 89 maize growers was (6.8 tonnes/hectare) higher than Bihar and India. Wheat yield was marginally higher than the state average for all classes. Fertilizer consumption of all crops was physically greater than the Bihar level, but among the three, maize was the largest consumer followed by rice in the sample (Fig. 2). A perception of NPK ratio showing an imbalance of nutrients was gained. Use of fertilizer and hiring of labour increased with farm sizes for all three crops but unlike fertilizer, rice required more hiring of labour (Table 6).

Cultivation of maize appeared to be a special feature of this dank, flood-prone district. Across farm classes, it is chosen by the maximum number of farmers, it claims the largest share of cropped area and fertilizer and it is the only crop grown totally for commercial motivation. Farm acreage under maize increases with farm size as the scatter plot of cross-sectional data of maize growers shows (Fig. 3), but a negative quadratic effect is present though statistically insignificant.

4.4 Marketing and Enterprises

Agricultural marketing in India is regulated by the APMC law (MoA&FW, Website), whereby an elected body is supposed to ensure good infrastructure and fair transactions with auctioning to discover prices. The degenerating system was failing to

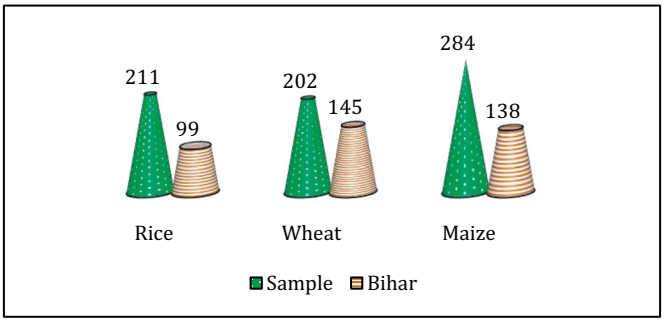

Fig. 2 Fertilizer (NPK) consumption (kg/ha)

Table 6 Average area and yield of study crops grown only by specific crop growing sample farmer households

Crop	Farm class	Marginal	Small	Medium	Large	Total
Rice	Area (hectare)	0.46	1.16	1.47	2.35	1.21
	Yield (tonnes/hectare)	1.65	1.74	1.79	1.34	1.67
	Production (tonnes)	0.76	2.02	2.63	3.15	2.02
Wheat	Area (hectare)	0.32	0.62	1.04	1.80	0.86
	Yield (tonnes/hectare)	2.66	2.45	2.41	2.33	2.47
	Production (tonnes)	0.85	1.52	2.51	4.19	2.12
Maize	Area (hectare)	0.54	1.04	1.54	3.05	1.34
	Yield (tonnes/hectare)	7.24	5.95	6.36	8.24	6.81
	Production (tonnes)	3.91	6.19	9.79	25.13	9.13

Source: Computed from sample data, DES (Website)
Note: Total is for all landed households in the sample (96). From the secondary data of Bihar, the average yield in tonnes per hectare in triennium 2014–2015 of rice, wheat and maize are 1.99, 2.21 and 3.27, respectively. Conversion: 1.5 kg paddy equivalent to 1 kg rice. Parenthesis () figures are number of crops growing farm households

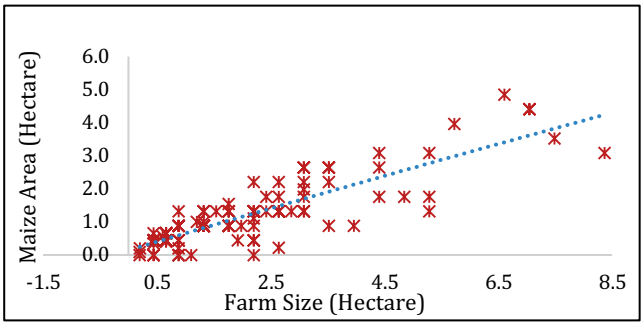

Fig. 3 Scatter plots of maize area against farm size

deliver its mandate in the 1990s as many markets remained under bureaucratic control without elections and became oligopsonistic as licensed traders bargained with disempowered farmers to set producer prices. The government has been trying to reform marketing by allowing easy entry and exit of buyers and allowing farmers to sell to larger more professional and corporate buyers or to organized cooperatives (Ghosh, 2013).

To take advantage of a larger market and improved technology accessible to more organized larger buyers, a law was circulated in 2003, recommending amendment of the state APMC law but success was limited. Bihar did legislate to do away with the old APMC law but failed to pass an amended (model Bill of central government) Act. In 2020, the central government again attempted the reform to allow selling to buyers outside the APMC market premises, but due to pressure from farmers, the Central Farm Act was withdrawn. This study was undertaken prior to this disturbance.

The Bihar government was procuring from farmers using three agencies. First, the Bihar State Food Corporation (BSFC) was procuring paddy and wheat at MSP under the decentralized procurement scheme of India followed by milling and distribution through the PDS. Cooperative movement at the grass root level was being revived with the Primary Agricultural Credit Society (PACS), the basic cooperative credit institution, forming a second procuring agency. Even in remote villages, they were equipped with storage infrastructure and computer linkage enabling early assessment of the crop situation. The Food Corporation of India (FCI) was the third agency that respondents complained was apathetic towards the purchase and storage of grains.

PACS was seen as a popular marketing outlet but there were complaints of 'high-handedness, collusion with local traders and also with banks' to delay procurement forcing farmers to sell at distressed prices. Table 7 shows that while maize was grown totally for commercial reasons, rice and wheat were also marketed by farmers, village traders being the leading buyer. Local powers bought maize from all classes and was the dominant buyer of rice and wheat from the LG class. The LG class sold almost 40% of its marketed maize in the market which was otherwise not a common outlet. Strangely, sale to private and also public organized buyers or processor was not reported by any respondent, but there were reports of a recent confrontation between farmers and PACS over payment default, delayed procurement and fraud. For each crop, the retail price at which the residents purchased from shops was the highest followed by the producer price at which the sample households sold. Subsidized PD price (PDSP) was the lowest (Fig. 4)

All three markets visited governed by ineffective committees before the APMC law was repealed had no official supervision at the time of the survey. Two of them found management from local agencies. A local food business managed the nearest market situated on the main road in the headquarters to transact only in rice and maize daily. Managed by a local charity organization the second market was further away from the headquarters and had a smaller size and catchment than the first one. Apart from daily rice and maize seasonal sale of wheat was reported. The third market having unutilized premises and no administrative offices and trader stalls was the most remote. Unsupervised it transacted in rice wheat and maize in a small paved yard with the smallest catchment. All three markets functioned on a daily basis but without refrigerators freezers grading equipment canteens and cow sheds. Traders complained of staff shortage and arranged their loading platforms and open storage. Field insight exposed the difficulties of the trader as also a sense of freedom brought by the lack of regulations

Maize is the major commercial crop in the area; nine maize traders in particular were interviewed. Between 25 and 65 years in age, the traders were male and educated but not beyond school level, except for the two largest traders who were both graduates in Commerce. Working for farmers' groups, they were sole proprietors of their businesses, operating in competition with other agencies without complaint. Both large traders had the business model of a company to which farmers and farmer groups delivered. Normally traders purchased maize with cash mostly from farm-gate from a catchment of 3–5 km, but large traders, some of whom were

Table 7 Marketed and sales outlets (%) of crop growing households of the sample

Type	Rice	Wheat	Maize hybrid
Marginal			
Marketed (% produced)	21.3	20.4	98.1
Outlet sold to (% marketed)			
Local chiefs	0.0	0.0	8.3
Village trader	50.0	83.3	66.7
Market	0.0	0.0	20.8
Private buyer	0.0	0.0	0.0
Public buyer	0.0	0.0	0.0
Others	50.0	16.7	4.2
Small			
Marketed (% produced)	51.6	22.8	66.3
Outlet sold to (% marketed)			
Local chiefs	0.0	25.0	20.0
Village trader	100	75.0	60.0
Market	0.0	0.0	15.0
Private buyer	0.0	0.0	5.0
Public buyer	0.0	0.0	0.0
Others	0.0	0.0	0.0
Medium			
Marketed (% produced)	37.9	46.7	95.1
Outlet sold to (% marketed)			
Local chiefs	25.0	22.2	22.2
Village trader	62.5	61.1	44.4
Market	12.5	0.0	33.3
Private buyer	0.0	0.0	0.0
Public buyer	0.0	0.0	0.0
Others	0.0	16.7	0.0
Large			
Marketed (% produced)	43.4	58.0	76.4
Outlet sold to (% marketed)			
Local chiefs	66.7	40.0	30.8
Village trader	0.0	30.0	23.1
Market	33.3	20.0	38.5
Private buyer	0.0	0.0	0.0
Public buyer	0.0	0.0	0.0
Others	0.0	10.0	7.7
All			
Marketed (% produced)	39.3	43.1	86.9
Outlet sold to (% marketed)			
Local chiefs	22.2	23.8	19.1
Village trader	61.1	59.5	51.2
Market	11.1	4.8	26.2

(continued)

Table 7 (continued)

Type	Rice	Wheat	Maize hybrid
Private buyer	0.0	0.0	1.2
Public buyer	0.0	0.0	0.0
Others	5.6	11.9	2.4

Source: Authors computation from survey data
Note: For production of crop growing farms, see Table 6. Outlets are Local chiefs, landlord, Sahukar and Mahajan; village trader, village trader; market, Mandi; private buyer, producer company; public buyer, state trader and PACS; others, others

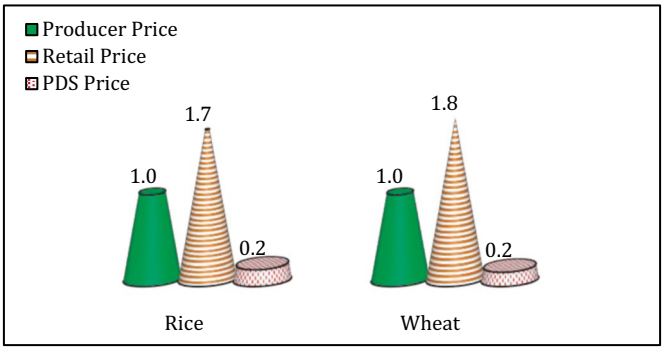

Fig. 4 Indices of producer price in crop wise in the sample

themselves landlords, reported buying large volumes at their stores from farmers even over 100 km away and also from other smaller traders. They paid both cash and cheque to farmers and only cheques to traders.

In farm-gate purchases, the transport cost, affected by road quality, was borne by the traders. Perceived as low, losses in transportation were attributed to the moisture content in the grain, faulty packaging, fracture in the journey and careless practices of farmers. A weighing machine (Dharma-kata) was available. Resourceful traders also had open or semi-permanent structured storage facilities. Loading and offloading, stationery, storage and license cost were reported expenses but not fumigation.

Using diesel threshing machines and local labour, enterprising households engaged in threshing maize for farmers for a fee. In villages, rice and wheat mills operated using electricity from public supply and private generators. Micro-enterprises were found only in the town where rice products (*Chura*, *Muhri*), wheat products (biscuits, bread), oils (mustard oil), poultry and dairy feed (maize and mustard) were manufactured in the sheds of family enterprises sometimes led by women entrepreneurs using family labour. Loans were taken from private sources and from bank via self- help groups.

4.5 *Profitability*

The total cost of cultivation relative to maize also shows the preference to maize (Fig. 5), the ratio exceeding one only for wheat among the MG class, but the relative cost came down and went up with farm sizes for wheat and rice, respectively. The LG class spent only 75% and 66% respectively on wheat and rice of what they spent on maize. Maize emerged as the only profitable crop across the classes, although for rice too the notional revenue from production exceeded the cost in the first three classes but was highly loss-making in commercial terms for the LG rice. Wheat suggested negative income potential except for the MG class but at the best, the returns were 20% of maize returns from a hectare.

4.6 *Consumption and Access to Food*

Rice was the main staple but the risk of flood limited its cultivation. Whatever rice produced served to protect the food security of the vulnerable households, supplemented by wheat which was grown in the rabi (safer) season if the soil remained suitable for planting. Farm production amounting to subsistence agriculture and wages as food were the dominant source of consumption. Yet 39% and 43% of rice and wheat, respectively, produced per household were also marketed (Table 7). Table 8, however, shows that the marketed share hardly represents the marketable surplus as households also purchased food grains for consumption and in fact the rice surplus was negative as the average household consumption of the total sample fell short of the farm production. Only some part of the farm production was retained for home consumption and a larger share was bought again from the market.

The LL and MG classes emerge as food deficient on the overall average even if cash needs for other purposes are ignored. Moreover, even the surplus at the average (Table 8) hides the plight of farmers who do not produce rice or wheat. The government steps in to counter the low purchasing power over open market supplies through subsidized PDS. In a scheme operational from 2007, coupons specifying

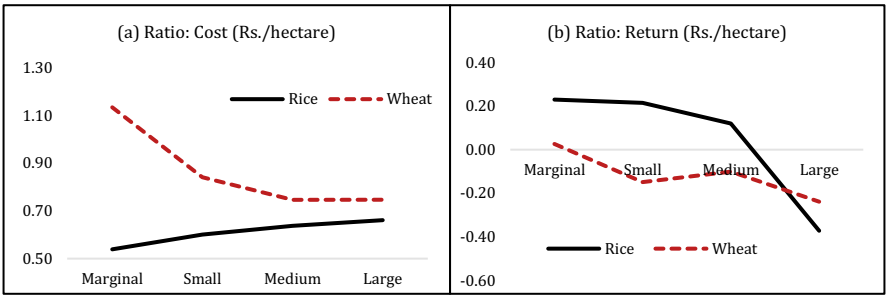

Fig. 5 Ratios relative to Maize

Table 8 Sources of food consumption of sample households in Khagaria

Average annual quantity (kg)/ household		Landless	Marginal	Small	Medium	Large	Sample
Rice	Production	–	336.7	778.0	1466.7	1312.7	734.7
	Consumption	813.6	628.8	704.4	759.6	890.4	740.4
	Farm produced	–	213.6	357.6	360.0	332.4	245.5
	Wage for food	115.2	–	–	–	–	23.0
	Public distribution	194.4	138.0	110.4	108.0	45.6	127.2
	Market	505.2	277.2	237.6	289.2	512.4	344.4
	Surplus	–	−86.8	9.5	48.2	32.2	−0.8
	Consumption/production (%)	–	186.8	90.5	51.8	67.8	100.8
Wheat	Production	–	594.0	1340.0	2381.0	3912.0	1412.0
	Consumption	843.6	698.4	844.8	872.4	1075.2	837.6
	Farm produced	–	369.6	685.2	758.4	1062.0	522.9
	Wage for food	124.8	–	–	–	–	25.0
	Public distribution	141.6	88.8	72.0	88.8	14.4	88.8
	Market	577.2	240.0	86.4	26.4	–	201.6
	Surplus	–	−17.6	37.0	63.4	72.5	40.7
	Consumption/production (%)	–	117.6	63.0	36.6	27.5	59.3

Source: Calculated from survey data

Table 9 Households (%) in farm classes holding ration card for food in PDS

		Types of card (%)			
Farm class	Ration card	APL	BPL	Antyodaya	Others
Landless	88	24	71	5	0
Marginal	94	50	43	7	0
Small	76	63	37	0	0
Medium	77	78	22	0	0
Large	85	100	0	0	0
Sample	84	58	39	3	0

Source: Authors computation from survey data

annual entitlements to wheat, rice and kerosene and their prices were distributed through village camps, organized by the local gram panchayat and block development office for beneficiaries to redeem a coupon each month. Mid Day Meal Scheme (MDM) and PDS were functional though marked by the high level of discrimination (Thorat & Lee, 2005). Dependence on PDS was more for rice than wheat which had a marketable surplus and was marketed as well as consumed at home to a greater extent (Table 8). In reality, farmers were found to resort to all three sources, namely, farm production, open market and PDS to meet food needs. Maize too served as a way of acquiring access to food through the market (Table 9).

PDS is seen as a critical support for food security through ties with the open market which was kept strong. Ration card was possessed by 84% of sample

households, but 58% of them had APL cards. Majority of the ration card possessors was the MG class, 7% of whom were very poor with Antyodaya cards and 43% of their cards were for BPL for whom prices were highly subsidized. The LG class was third among the ration card holders but all of them were in the APL class paying the high price (cost price of distribution), while cards possessed by SM and MD classes were distributed between APL and BPL charging varied prices.

The economics of the food security of the climatically compromised community having access also to government support is calculated by the notional access to food assuming the entire volume of a crop produced in a hectare is converted to cash to buy food and comparing with the potential production of the food crops as an alternative. The relative producer prices and differentials across the three prices were already seen (Table 10). For MG rice grown and sold could buy rice for consumption of 3.4 tonnes per hectare, higher than its yield at 1.65 tonnes accessible if rice was grown on the same land. This is not so in all cases and the access was negative in the LG class. At the retail price, the access was much lower but maize gave greater access in all cases. However, farming was no means the only source of livelihood. Off-farm jobs in the state and migration to other states added to household incomes and some households also supplemented earnings by participating in NREGA, but it appeared that all the supplementation was compelled by the shortage of income from farming to meet daily needs.

Table 10 Access to food grain from market (tonnes/hectare)

			Marginal	Small	Medium	Large
Access to rice	PDS	Rice	3.42	1.35	0.86	−3.93
		Wheat	0.39	−0.93	−0.72	−2.52
		Maize	14.88	6.28	7.17	10.57
	Retail	Rice	0.37	0.14	0.09	−0.42
		Wheat	0.04	−0.10	−0.08	−0.27
		Maize	1.59	0.67	0.77	1.13
	Yield	Rice	1.65	1.74	1.79	1.34
Access to wheat	PDS	Rice	5.13	2.03	1.30	−5.90
		Wheat	0.59	−1.40	−1.08	−3.79
		Maize	22.33	9.42	10.75	15.86
	Retail	Rice	0.44	0.17	0.11	−0.50
		Wheat	0.05	−0.12	−0.09	−0.32
		Maize	1.90	0.80	0.91	1.35
	Yield	Wheat	2.66	2.45	2.41	2.33

Source: Authors' computation from survey data

5 Motivation to Produce Crop

Selection equations suggest (Table 11) the tendency of taking up any of the three

Table 11 Regression results of area equations of sample (with Heckman correction): sample period—2014–2015 (cross-sectional data)

	Rice		Wheat		Maize	
Independent variables	Coef.	Z-stat	Coef.	Z-stat	Coef.	Z-stat
Economic						
Incentive	4.42	2.03**	2.39	2.42**	2.68	1.73*
Food (rice) security					−0.002	−2.04**
Distance from river*incentive	−0.51	−1.73*	−0.67	−2.07**	−1.15	−2.13**
Distance from road*incentive			−0.77	−2.77***		
Remittance	−0.000	−1.00	0.000	1.80*		
Geography						
Land waterlogged dummy			−0.83	−3.14***	0.59	2.05**
Distance from river	0.67	2.03**	0.79	1.97**	0.90	2.05**
Distance from road	0.69	4.87***	1.06	2.94***		
Agronomic						
Farm size			0.31	9.46***	0.16	2.62**
Irrigation^^	0.32	10.28***			0.32	6.08***
Demographic						
Female workers^					0.70	1.03
Migration ratio^	4.92	3.20***	−1.55	−2.40**		
Constant	−5.47	−2.21**	−2.36	−1.89*	−1.89	−1.37
Select						
Farm size	0.40	4.08***	0.87	5.40***	1.14	5.20***
Squared farm size	−0.020	−3.22***	−0.04	−3.59***	−0.05	−3.85***
Female workers^	−1.81	−2.31**	−1.19	−1.23		
Land waterlogged – dummy	−0.65	−1.86*				
Migration^					−3.52	−2.47**
Distance from river			−0.04	−1.10		
Distance from road			−0.23	−1.43		
Constant	−0.46	−1.12	−0.30	−0.56	−0.95	−2.99***
Lambda	−0.46	−0.90	−0.43	−1.04	0.20	0.41
Rho	−0.46		−0.48		0.20	
Sigma	1.000		0.89		0.97	
Number of observations	116		115		109	
Censored observations	40		78		78	
Uncensored observations	76		37		31	

Source: Authors' computation from survey data

Note: Incentives—producer price of crop relative to identified substitute crop. Substitute crops—rice, kharif maize; wheat, rabi maize; maize, wheat. Food security: producer price/PDS price of food crop. ***, ** and * denote the level of significance at 1%, 5% and 10%. ^ Ratio to workers, ^^ ratio to total cropped area

crops for cultivation is positively related with farm size (representing access to cultivable land) though the response was relatively less for rice. The quadratic effect of the sown area was noted in all cases suggesting that the relation with land available was not monotonic. Female dominance among working members was a discouragement for growing both rice and wheat, while migration intensity of workers discouraged maize cultivation for earning reflecting labour and food security implications. Possession of waterlogged land was a deterrent to rice cultivation perhaps because of the seasonal attribute. Other chosen variables including economic incentives were not relevant for crop selection.

Although not every farm household had the privilege of growing a crop, once a crop is chosen for cultivation, varied factors come into play in deciding the acreage of a chosen crop. Producer price ratios served as incentive variables for explaining acreage in all cases only if an interaction term with the distance for the river is allowed. The substitution effect is shown by the incentive having a positive significant effect with expectedly maize and wheat substituting each other in the rabi season and rice and maize in the kharif season but for maize the rabi season effect dominated. In all cases, the incentive was stronger for farms located closer to the river, so the incentive did not really emerge as the prime driver of acreage, while geography was a determinant even for the incentive effect. In fact, food security in terms of the availability of rice seemed important for the commercial crop maize which was made attractive or even imperative by the falling producer price of rice relative to its PDS price. The use of the price variable for rice was enabled by the variation of PDS prices across households as seen from the card holding pattern (Table 9), but the limited variation could be a reason for not finding the effects of the wheat price variable. Remittance is an economic factor affecting wheat acreage.

Distance from the river expectedly had a positive effect on the acreage of each crop. Distance from the road has a positive effect on acreage though only for rice and wheat, probably for food sufficiency. Farm size was important for only wheat and irrigation intensity had a strong positive effect on rice and maize acreages. A higher migration ratio that can undermine labour availability reduced wheat acreage but contrary to expectation enhanced rice acreage. Unlike in the selection equation, the prevalence of waterlogging has no effect on rice area but it reduced wheat acreage but helped maize acreage.

6 Conclusion

The vulnerability of households of the Kosi Basin contributes to the poverty of the state of Bihar. This study conducted in a district in the Kosi-Ganga Basin of Bihar observed that producers regularly bear the damages of land lost and soil sedimentation due to flooding and adapt to the hardships by mass migration to distant places by growing commercial crop maize while also securing their food security with the help of subsidized public support.

The data suggests that larger farm size is not an indicator of economic well-being in this dank environment where much of farming is not remunerative. All farm size classes suffer floods, waterlogging and loss of land. In fact, the large average farm size is a way of coping with adversity through family cohesion and mutual support in large joint families with undivided land. Growing food crops is risky, especially rice in the monsoon season, but with inadequate drainage, the effect of excess water might even creep into the rabi season too. Maize, a commercial crop that can be grown in drier seasons, is increasingly grown as an income buffer for generating higher yields, larger cash returns and greater access to food from the market.

Traders and local power agents are dominant sales outlets of the market that producers encounter. Open market and farm production both serve as sources of consumption, but PDS has been a more powerful support to their food security especially as small holding classes do not generate enough food or income to meet their needs and not all farmers are privileged with land suitable for growing rice and wheat. In fact, nearness to the river is a strong deterrent to growing of the food crop rice. Rice as a staple food appears as a risky crop to cultivate in the region. An econometric model with Heckman correction shows that despite the constraints, economic incentives are important for crop choice with maize being a major alternative to food crops rice and wheat, but the location of a farm with respect to the river and the road along with other agronomic and demographic factors are also determinants of crop choice.

The misery brought by natural conditions may aggravate if the eastern Himalayas further warm up as apprehended by scholars and glaciers melt releasing sequestered water down the unconsolidated steep slopes. This is a problem that requires public planning and government intervention. Weather forecasts and market intelligence can be a minimum need, but the government may continue and intensify support for food security and devote research to identify alternative farm or non-farm livelihood which will be viable in the condition. Social support for health and education will improve human resources for a safer future. Collaboration among river-sharing countries can help to improve weather forecast, trade and food security, drainage of land and data recording regarding land, water, power and climate.

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