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Are embankments a good flood control strategy? A case study on the Kosi river

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Abstract

Whether embankments should be used to control floods is a question of great importance in the eastern Gangetic plain, where embankment breaches cause severe flood damage every year and huge damage due to major breaches every few years. Critics of the embankment policy have called for a strategy of living with floods by building dispersed infrastructure to cope with floods. However, no cost–benefit analysis of alternative strategies is available. This paper makes a first pass at evaluating embankments. Using 2 years or more of data from 504 households in 28 villages in the floodplain of the Kosi river in north Bihar, the paper compares agricultural output, wage incomes, unemployment and other indicators of well-being in villages subject to flooding from rivers with those from villages not subject to such flooding. The paper finds that, for the most part, villages subject to river flooding are no worse off than villages not subject to such flooding. Thus, the evidence provides no support for the embankment strategy.

Keywords: Agricultural income; Cost–benefit analysis; Embankments; Flood control; Floods

1. Introduction

The eastern Gangetic plains and the adjoining floodplain of the Brahmaputra river have suffered from catastrophic floods, not only in recent decades, but far back into recorded history. It is well known that these rivers deposit large amounts of silt and eventually change their course as a result, often causing huge flood damage. Of them, the Kosi, which originates in Tibet and Nepal and joins the Ganges in Bihar, is known to be one of the most dynamic. Between 1736 and 1950, the Kosi shifted its course westwards across north Bihar by some 140 km (Hill, 1997). It shifted abruptly by several kilometres once every few years, causing devastation each time. The building of a barrage in Nepal in the 1950s and subsequent embankments along its course in Bihar appear to have halted the movement of the riverbed. But the embankments have breached frequently, with major breaches occurring once every 6 years, on average (Mishra, 2008a). For example, in October 1984, a breach in the eastern embankment in Saharsa district inundated 500 villages, leaving half a million people homeless and killing at least 200 (Hill, 1997).

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Embankments were built because it was thought that they would provide flood protection and enable an additional crop to be grown (Appu, 1973). However, the building of embankments on the Kosi and other Himalayan rivers with high silt loads was controversial from the start. For example, at the Patna Flood Conference in 1937, the Chief Engineer of Bihar, G. F. Hall, said that he:

'… gradually came to the conclusion that not only was flood prevention undesirable but that bundhs [embankments] are primary causes of excessive flooding, and I think that a majority of people now agree that provided they are evenly distributed and are of moderate depth, north Bihar needs floods and not their prevention, notwithstanding the numerous articles in the press to the effect that the government must take steps to prevent floods' (quoted in Mishra, 2008c).

Several authors have called for a strategy of dispersed or 'soft' infrastructure to cope with inevitable floods rather than relying on the 'hard' infrastructure of embankments (Mishra, 2008b; Sinha, 2008; Dixit, 2009). So far there has not been a cost–benefit analysis of an alternative strategy. In the absence of more comprehensive data, this paper attempts to shed some light on these issues using a survey of 504 households in the Kosi basin following the last major flood in 2008–2009. The paper does not attempt a full cost–benefit analysis but confines itself to evaluating the claim that embankments raise agricultural productivity. It finds that, with some qualifications, villages whose fields are regularly flooded are no worse off than villages not subject to being flooded by rivers. G. F. Hall's misgivings about embankments seem to have been well-founded. It is true that this paper presents data for only two monsoons, and there is considerable inter-annual variability in floods. However, this paper argues that at least the burden of proof has now shifted to those who claim that embankments have raised incomes and well-being.

On 18 August 2008, the Kosi breached its embankment in Nepal close to the Bihar border. The westward loop taken by the river was cut off, flooding a vast and roughly triangular area, with its apex at the breach and its base at the Kosi where it flows east 150 kilometres to the south. According to official sources, 493 people were killed and some 3,500 reported missing after the disaster; 3.3 million people in Bihar were affected and at the peak of the flood, 440,000 were living in camps (Anonymous, 2010). The Government of Bihar estimated the cost of reconstruction and rehabilitation to be 148 billion (148×10^9) rupees ($3 billion) – about 60% of its annual revenue (Anonymous, undated).

In February and March 2009, a survey of 10 villages in Bihar that were flood affected was conducted. These 10 villages, labelled 1–10 in Figure 1, were chosen to lie in a roughly north–south line following the course of the floodwaters that ran east of the river bed. Villages 1–8 were flooded by the Kosi after it breached the embankment; they are referred to below as the 'unexpectedly flooded villages'.

Village 9, near the regular course of the Kosi, and Village 10 near the Ganga, are flooded during the monsoon every year by their respective rivers, and are adapted to flooding. In fact, both these villages have most of their fields inside an embankment[1]. Some results from village- and

[1] It may seem peculiar for villages to be inside an embankment. The embankments were built several kilometres from the river bed, since an attempt at narrower confinement of the river would obviously have been doomed to failure. Consequently, villages really ought to have been moved outside of the enclosed embankment area but, perhaps inevitably, and given the failure of the government to arrange for proper rehabilitation, this did not happen. All of this was foreseen by some members of the villages, and there was then a political struggle between those villages which were thought to benefit from flood control and the 'embanked' villages; the latter lost. See Mishra (2008c) for a comprehensive history.

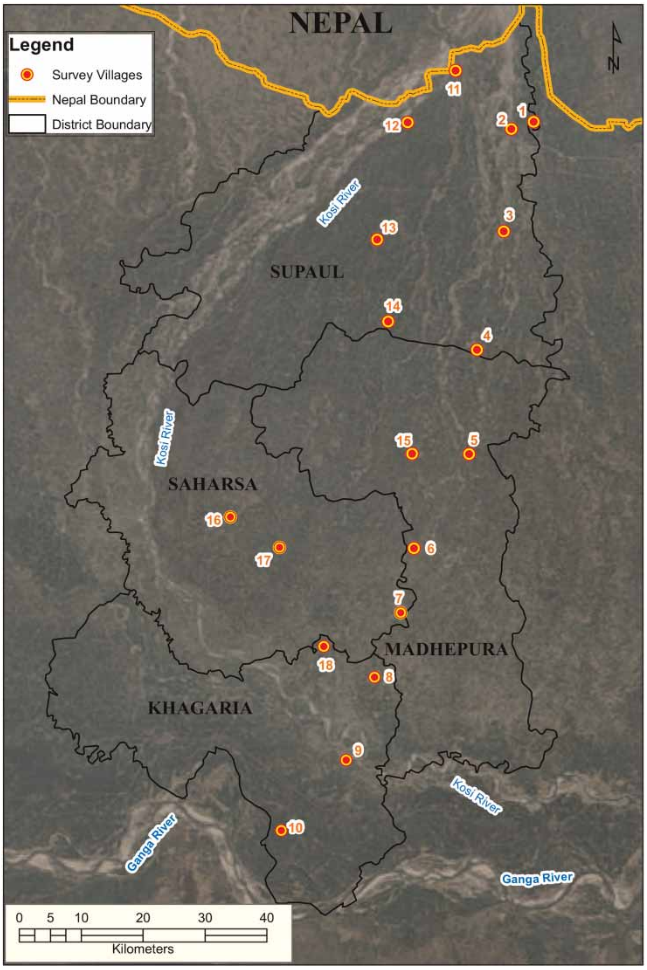

Fig. 1. Location of study villages. (Full colour versions of all the figures in this paper appear online.)

hamlet-level data from this survey were reported in an earlier paper (Somanathan & Somanathan, 2009)[2].

In April and May 2010, the 10 villages were re-surveyed together with an additional eight villages[3]. The additional villages, numbered 11–18, lie to the west of the eight unexpectedly flooded villages and

[2] Indian villages often have more than one hamlet. A hamlet is a cluster of houses and may be as much as a kilometre away from another hamlet in the same village.

[3] 28 households were interviewed from each village. A sketch map of each village was made first, and the number of households ascertained. This was divided by 28 to get a number, n. The surveyors then traversed the whole village interviewing every nth household. In each hamlet, a hamlet questionnaire was filled in with at least two respondents to confirm information. The respondent was the household head, if available, and another responsible adult, if not. In the second survey of Villages 1–10, the original respondent was interviewed, if he/she was available. Interviews lasted about one and a half hours.

were chosen for comparison. Our intention was to choose villages that were far enough away so that they were not affected by the breach in the Kosi embankment. One of these villages, number 12, has most of its fields inside the embankment of the Kosi (downstream and to the south-west of the breach), so that its fields are flooded by the Kosi every year. The fields of Village 18 are also flooded during the monsoon every year by a small river, the Sursa. Villages 9, 10, 12 and 18, since they are adapted to flooding by rivers during the monsoon, are referred to below as 'regularly flooded villages'.

The remaining six villages (Villages 11 and 13–17) are referred to below as 'control villages' since they are not regularly flooded by river overflow, nor were they unexpectedly flooded due to the embankment breach. It should be kept in mind, however, that such villages may also have localized flooding during the monsoon due to rain collecting in low-lying lands. This is common in the eastern Gangetic plain. See Table 1.

In what follows, the three groups of villages are compared over the period July 2008 to March 2010. The purpose was to ask whether a strategy of allowing floods but building dispersed infrastructure to cope with them would be better than the current strategy of flood protection based on embankments. The paper focuses on comparing the regularly flooded villages with the control villages. Note that the regularly flooded group includes two kinds of villages: Villages 9, 10 and 12 which are inside (or have most of their fields inside) embankments on major rivers (the Kosi and the Ganga), and Village 18 which is subject to river overflow from a minor river. By including both kinds, all the likely effects on the different villages of removing embankments are included. Villages currently protected by embankments but close to a major river are likely to face flooding that may be similar to that faced by Villages 9, 10 and 12. Of course, they are likely to be better off in one respect: floodwaters not confined in embankments are likely to not rise as high. Villages further away from the river may, when embankments are removed, find themselves in a situation more like that of Village 18.

Thus, the regularly flooded group is meant to be a rough proxy for what villages on major riverbanks would be like if their embankment protection were removed and if no compensating infrastructure to help them cope was built. The control group is meant to proxy their situation under the status quo (but only in a normal year, when there is no major breach and flood protection really works). The unexpectedly flooded group will provide some information on the lasting impact of a major embankment breach some months after it occurred.

In Section 2, some background information on infrastructure and occupational structure in the villages is provided. In Section 3, the gross returns to land among the three types of villages (unexpectedly flooded, regularly flooded and control villages) are compared. In Section 4, the returns to labour are compared and food sufficiency is examined. Section 5 briefly examines and compares some other characteristics and outcomes among the three groups, including schooling, health and some measures of wealth, while conclusions are drawn in Section 6.

2. Infrastructure and occupations in the study villages

The three types of villages are quite similar in terms of the rarity with which household amenities are present. Only about 6% of households in the sample have electricity for lighting and the

Table 1. Village classification.

	Unexpectedly flooded	Regularly flooded	Control villages
Village numbers	1–8	9, 10, 12, 18	11, 13–17

differences between the three groups are not statistically significant. None of the sampled households have access to piped water (most of them use handpumps), and only about 10% have toilets. Again, the differences in the frequency of these amenities across village types is minor. The four regularly flooded villages are not noticeably different from the others with regard to other infrastructure. The exception to this statement is that Village 10 does not have a school at all, which is clearly unusual; only one other surveyed village does not have a school.

Farmers, that is, the owners or operators of farms, constituted about 34% of the workforce in the sample, while wage workers in agriculture constituted about 10%. Casual (daily-wage) workers outside agriculture were another 36% of the labour force, and about 8% of the labour force was unemployed (Table 2). Of the 20,000 person-months in the labour force from July 2008 to March 2010, more than 18,000 were man-months. The workforce appears to be overwhelmingly male, at least as reported by respondents. This might understate female labour force participation since that could have been considered a secondary occupation in the case of many women.

3. The returns to land compared

Since agriculture constitutes a large share of the labour force, the effects of flooding on crop output are first examined here. A second reason for comparing agricultural productivity in the three types of villages is that land, unlike labour, is immobile. Thus, while the effects of flooding on the returns to labour might be spatially diffused via migration, the returns to land cannot be. Data were not collected on input costs, so the returns to land mentioned below are gross returns, not net returns. There is no reason to believe that this would bias the comparisons being made.

Table 2. Percentage of person-months out of those in the labour force in various main occupations in a given month from July 2008 to March 2010.

Main occupation	Unexpectedly flooded villages	Regularly flooded villages	Control villages	All villages
Wage worker in agriculture	11	12	8	10
Self-employed in agriculture (farmer)	31	41	36	34
Daily-wage worker outside agriculture	38	35	33	36
Salaried worker outside agriculture	4	3	8	5
Self-employed outside agriculture	10	5	5	7
Unemployed	7	4	11	8
Total percentage	100	100	100	100
Total person-months in labour force	9,282	4,179	6,552	20,013

Notes: Columns may not add to exactly 100 due to rounding up/down; the unemployment rate, if measured on a daily basis, would probably be higher.

Figure 2 shows the total value of crop output per acre[4] owned or operated by households. Note that the denominator is not cultivated acres, but all acres, cultivated and uncultivated. Thus it takes into account the loss of output when lands are left uncultivated due to floods.

The monsoon arrives in Bihar in mid-June and lasts until September. This is the Kharif cropping season and paddy is the most common crop. However, if flooding is severe, there may be no Kharif crop. Following the Kharif season, maize and wheat are the most common crops, generally planted in November. The November–March season is known as the Rabi season. Following the Rabi season, fields are sometimes left fallow during the spring and summer, but may be planted with a third crop, for example jute, pulses, paddy, or maize. Data were not collected on crop output in the Kharif (July to November) season of 2008 in the flooded villages since the crop (mostly rice) was entirely destroyed by the unexpected flood. However, it is possible that in Villages 9 and 10, where flooding was expected, crop output may have been positive. Unfortunately, we do not have these data.

What is immediately striking from this figure is the high Rabi (winter) output (mostly maize and wheat) in the two regularly flooded villages. Villagers say that this is due to silt deposition from flooding. This winter yield is large enough to compensate for the very limited Kharif crop so that, over the course of an agricultural year, output per acre is about the same as in the control villages – to be precise, over the three successive seasons starting with the 2008–09 Rabi season, the value of output per acre in the regularly flooded villages exceeded that in the control villages by Rs 1,103/acre, with the difference not being statistically significant ($p = 0.17$). If the value is aggregated over three successive seasons starting with the

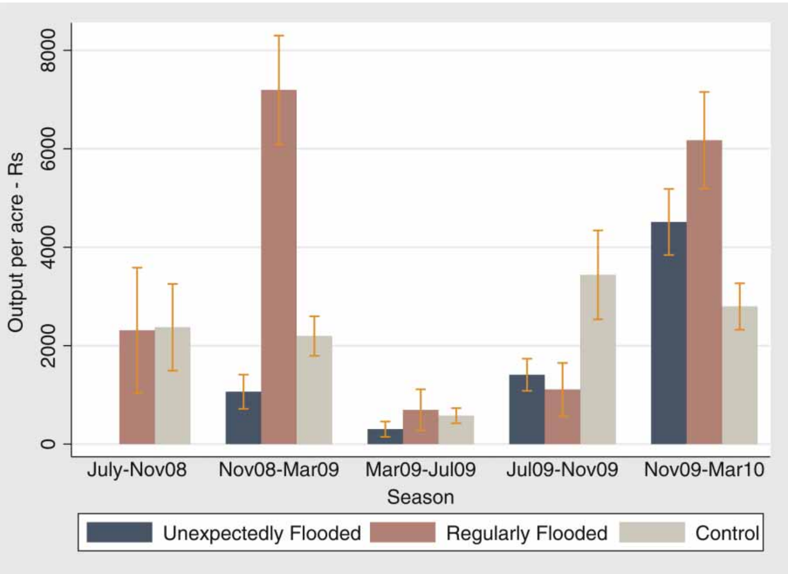

Fig. 2. Rupee value of output per acre of cultivable area. *Note*: Bars are means taken over all households in each group. 95% confidence intervals are superimposed. The data above for the regularly flooded villages in July–November 2008 are only from Villages 12 and 18 because data for that season were not collected in Villages 1–10.

[4] 1 acre = 0.4047 hectares.

2009 summer season, output per acre in the regularly flooded villages falls below that in the control villages by Rs 116/acre, with the difference again not being statistically significant ($p = 0.90$).

The patterns in the value of output per acre of farmland are broadly consistent with the data on the mean acreage cultivated per farm. Acreage planted in the regularly flooded villages doubled from slightly more than 1 acre per farm to over 2 acres per farm between the monsoon season of 2009 and the succeeding winter season, while it declined from about 1.8 to 1.5 acres per farm in the control villages during this period.

4. Labour earnings and food sufficiency compared

Focus in the study has been placed on male workers employed in agriculture and other daily-wage workers because these constitute a majority (72%) of wage earners, and are poorer and less secure than those with permanent employment.

The impact of the loss of earnings from the flood in the villages that suffered from the embankment breach is clearly visible in Figure 3. Although less sharp, the two regularly flooded villages also suffered a loss of earnings during the monsoons of 2008 and 2009. The eight control villages show a dip in earnings during the 2008 monsoon, though not during the 2009 monsoon. It is clear from Figure 3 that the differences in earnings between the three types of villages are not statistically significant, except during the months immediately following the embankment breach when Villages 1–8 suffered disastrous damages. By the second quarter of 2009, average earnings in these villages had recovered to their pre-flood level and are no longer distinguishable from those in the other two categories of villages.

Since about 80% of the wage workers are not in agriculture, it is perhaps not so surprising that the impact of flooding in the regularly flooded villages on mean monthly earnings is not very marked. Figure 4 shows mean

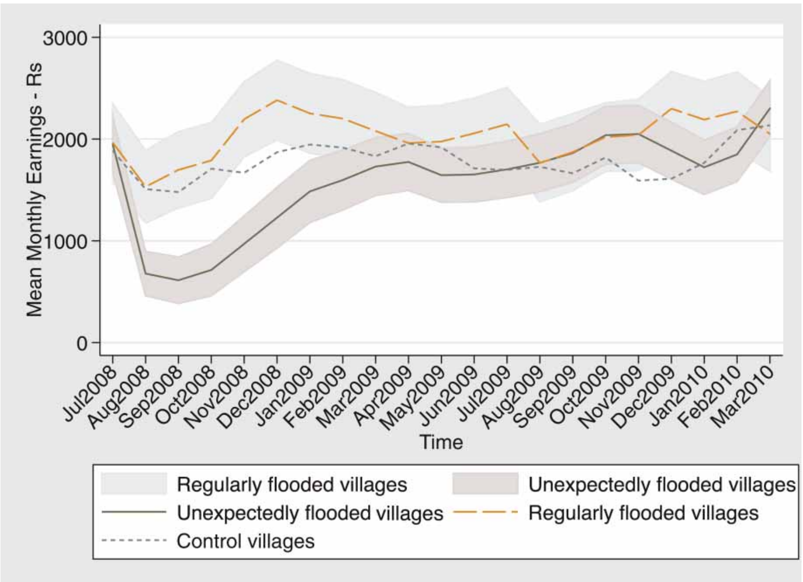

Fig. 3. Monthly earnings of male agricultural and casual workers. *Note*: 95% confidence intervals for the unexpectedly and regularly flooded villages are shown as shaded areas.

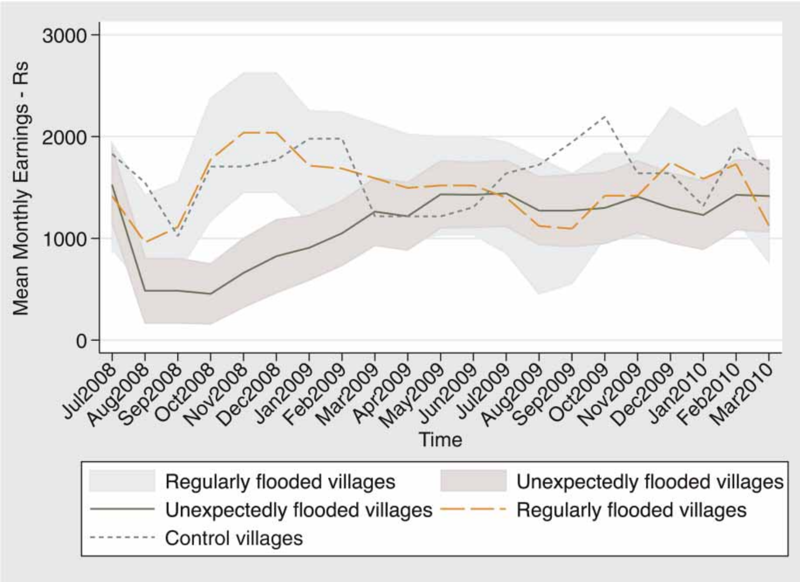

Fig. 4. Monthly earnings of male agricultural workers.

monthly earnings of only those working in agriculture; not surprisingly, the decline in earnings in the regularly flooded villages during the monsoon season is greater in this figure.

What is perhaps most surprising about the data in Figures 3 and 4 is that there is no significant difference in mean monthly earnings between the two regularly flooded villages inside embankments and the control villages.

Figure 5 shows days employed. The pattern is exactly the same as for monthly earnings. What this shows is that the collapse of earnings in Villages 1–8 due to the embankment breach was driven by a loss of employment and not by a fall in the daily wage. Figure 6, which plots monthly earnings divided by days employed, confirms this impression. In fact, the slight rise in the daily wage during periods of flood suggests that individuals over-stated the loss in employment during such periods. Since these data are all based on recall over a period of at least a few months, this is not surprising. In any event, it is clear that wages did not fall in response to even massive negative shocks to labour demand, although the features of the labour market that are responsible for this are not clear.

This being the case, it is possible that the loss of earnings from a reduction in the demand for labour during floods could be unequally distributed among workers. Some may be unemployed more frequently than others. In this case, mean monthly earnings will not sufficiently capture the losses to these workers. The entire distribution of earnings needs to be examined.

During the monsoon seasons of 2008 and 2009, in the regularly flooded villages, a quarter or more of workers in the sample had zero earnings. In the control villages, the bottom quartile also had zero earnings during the monsoon season of 2008 but were better off during the monsoon season of 2009[5]. Clearly, the relatively small dips in mean monthly earnings in these villages during the monsoon do not capture the full extent of wage losses from flooding. Presumably, as suggested by the data on

[5] The control villages saw some localized flooding due to the collection of rain in low-lying fields in 2008, but not in 2009.

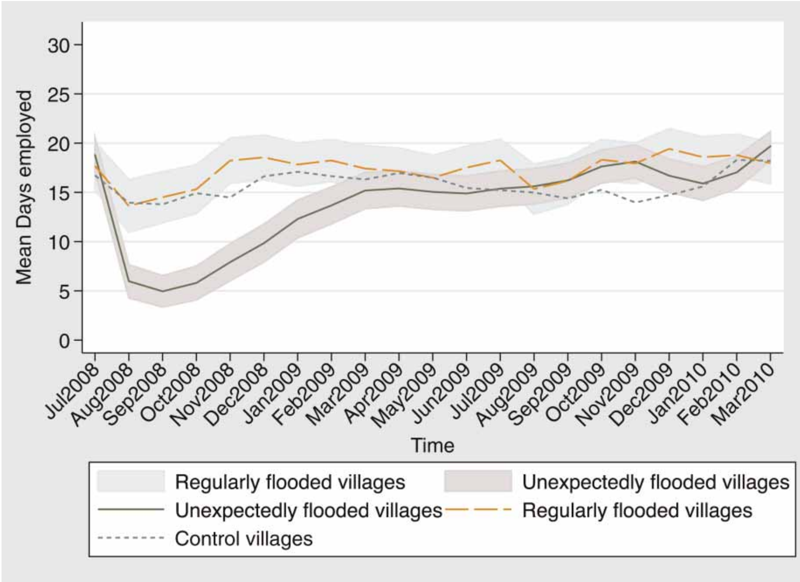

Fig. 5. Days employed: male agricultural and casual workers. *Note*: 95% confidence intervals for the unexpectedly and regularly flooded villages are shown as shaded areas.

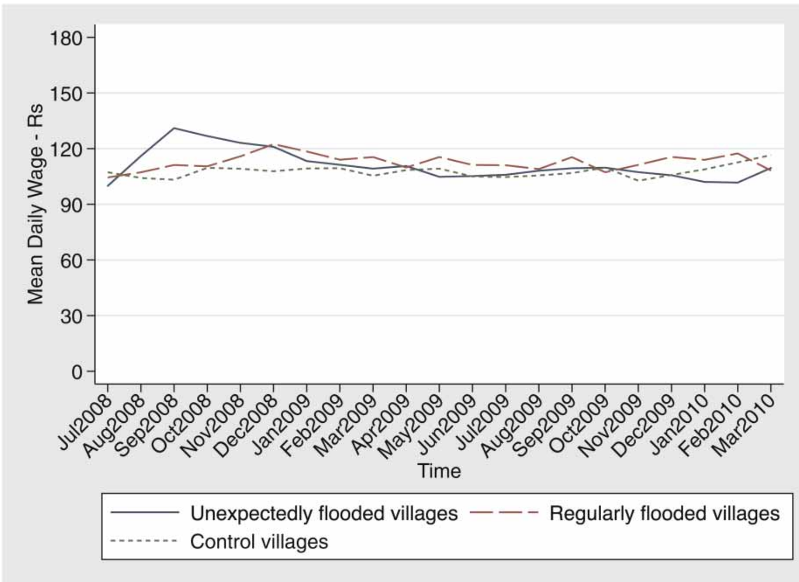

Fig. 6. Daily wages for male agricultural and casual workers.

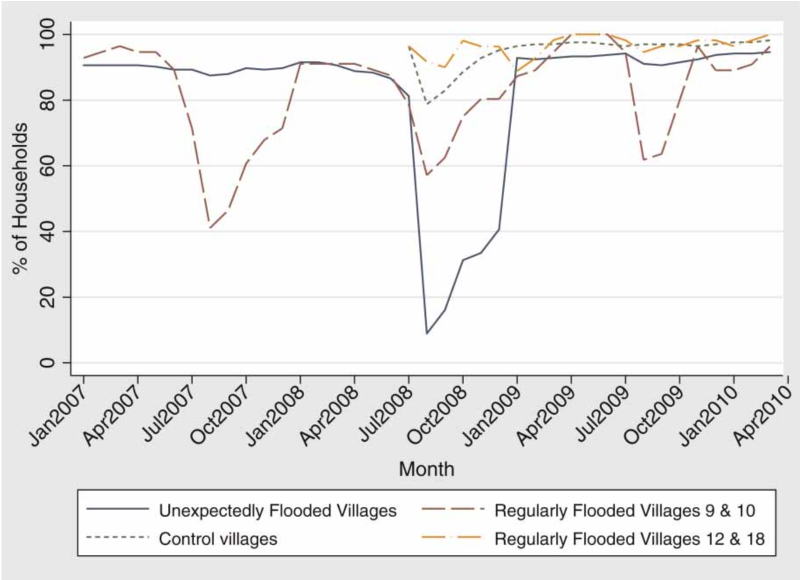

Fig. 7. Percentage of households reporting food sufficiency.

crop output (Figure 2) and agricultural earnings (Figure 4), agricultural workers were the ones at the bottom of the earnings distribution during times of flooding.

An examination of the distribution of earnings also reveals that the fall of earnings to zero in the bottom quartile in the unexpectedly flooded villages persisted into October 2009, 6 months longer than the apparent recovery of mean earnings.

Another way to examine the impacts of flooding on the poor is to look at food sufficiency. The sampled households were asked in which months they got three full meals a day. Figure 7 displays the resulting picture.

There are steep dips in the fraction of sample households getting adequate food during the monsoon months when flooding occurs. This is consistent with the collapse in wage earnings at the bottom of the distribution during periods of flooding. The worst impact was, of course, due to the embankment breach in August 2008. However, the regularly flooded Villages 9 and 10, both of which have fields inside embankments, also saw steep declines in the fraction of households getting three full meals a day. The other two villages regularly subjected to flooding by rivers, only one of which has fields inside an embankment, were not as badly affected. Indeed, they were not even as badly affected as the control villages in 2008 and did no worse in 2009, the 2 years for which data on all villages are available.

If the regularly flooded villages are grouped together and their data for 2008 and 2009 alone are used to produce a graph, we see that they had lower food sufficiency than the control villages in 2009 but not in 2008 (Figure 8). The worse performance of the regularly flooded villages on this score is clearly driven only by Villages 9 and 10 (both inside embankments).

The results appear to show that the returns to land in the regularly flooded villages are no lower, on average, than in the control villages. Nor are the returns to labour. However, flooding results in both agricultural output and labour earnings at the bottom of the distribution being much more volatile over the course of a year in the regularly flooded villages than they are in the control villages, because the latter are less subject to

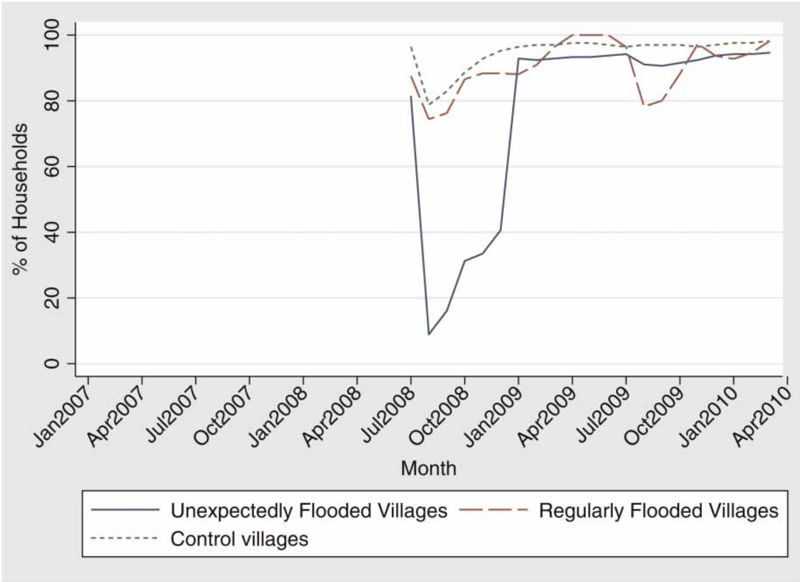

Fig. 8. Percentage of households reporting food sufficiency, with all four regularly flooded villages grouped together.

flooding. This results in the poor being worse off in some years in the regularly flooded villages, as evidenced by the data on food sufficiency. It must be remarked, however, that this is driven entirely by villages inside embankments and is not the case for Village 18, although that village is flooded by the Sursa river every year.

5. Other outcomes compared

The three types of villages do not appear very different in terms of levels of schooling achieved, both by children still in school and by adults. Levels of educational attainment are very low. The mean for adult women is about 2 years of schooling and that for men about 5 years of schooling.

To consider health outcomes, self-reported data based on recall over the period January 2009 to March 2010 can be studied. It might be expected that villages more prone to flooding have a higher incidence of diarrhoeal disease and other infectious diseases; in fact, such diseases were no more frequent in the regularly flooded villages than in the control villages over the whole period among the 3213 individuals in the sample[6]. However, these illnesses were more frequent in the unexpectedly flooded villages than in the controls or in the regularly flooded villages, and the differences are statistically significant at the 5% level for diarrhoeal disease and at the 1% level for all infectious diseases added together. These results hold when controlling for age and sex. When one considers all diseases, both infectious and non-infectious, there are no statistically significant differences between the different classes of villages. These results suggest that there was an increase in infectious disease in the unexpectedly flooded villages following the disaster and the attendant waterlogging. However, the regularly flooded villages were no worse off than the controls.

[6] These disease frequencies were, in fact, slightly lower in the regularly flooded villages than in the control villages.

The three types of villages were next examined to see if they exhibit any differences in measures of wealth such as ownership of consumer durables, farm equipment, livestock and financial assets.

Only about 5% of the 504 sample households owned TV sets, not surprising in view of the limited access to electricity. About 20% owned a radio or TV (or both). About 66% of households had at least one telephone[7]. There were no statistically significant differences in the ownership of any of these goods between village types, nor in the total value of such goods owned.

The total value of agricultural equipment (pumpsets used for irrigation, threshers, tractors) and vehicles (bicycles, motorcycles, cars and jeeps, bullock carts) showed no statistically significant difference across village types. Except for bicycles, ownership of these goods was rare, with fewer than 10% of households possessing them. Fifty-five per cent of households owned bicycles and they were more common in the control villages than in the other two groups, with the differences being statistically significant at the 1% level.

The average holding of large livestock (cows, bull and bullocks, and buffaloes) in March 2010 was 1.3 head per household, with this number being about 1.5 for the regularly flooded and control villages, and about 0.8 for the unexpectedly flooded villages. In July 2008, before the flood, the unexpectedly flooded villages had about 0.8 head per household more of large livestock than the other two groups. Livestock loss was clearly considerable in the unexpected flood. In both periods, the difference between the regularly flooded and control villages was not statistically significant.

About 39% of the sample households had bank accounts. This figure was 32% in the control group, 35% in the regularly flooded group and 47% in the unexpectedly flooded group. Only the difference between the unexpectedly flooded group and the other two is statistically significant. The differences in reported savings, either in bank accounts or cash, between the groups was not statistically significant at the 10% level. This could be because the less wealthy households in the unexpectedly flooded villages had drawn down their assets after the flood. It could also be due to systematic under-reporting of the amounts.

6. Conclusions

The most striking finding from the comparisons between regularly flooded and control villages made here is that the gross value of crop output in the regularly flooded villages is higher, or at least no lower, than that in the control villages. This is especially striking since three out of four of the regularly flooded villages in this sample are located inside embankments and, therefore, are highly exposed to seasonal and concentrated river flooding. The second major finding is that mean wages of agricultural and casual workers are no lower in these villages than in the controls. Third, these villages do no worse on measures of schooling, health, wealth and household amenities.

There is one big difference between these villages and the controls, and that is that agricultural output varies much more sharply over the year. This results in dips in the proportion of households getting sufficient food during the monsoon. Although this pattern was also seen in the control villages in 2008, when some of them suffered flooding from heavy rain, it did not appear in the control villages in 2009. Poor workers evidently lack the means to smooth consumption between seasons and the loss of the monsoon crop to flooding causes them to go hungry during the monsoon.

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[7] These were most likely nearly all mobile phones.

The results on crop output, mean wages, assets and other measures of welfare, such as schooling and health, indicate that the regularly flooded villages (three of them with most of their fields inside embankments on major rivers) are no worse off than the controls that are not near rivers. Thus, one of the major motivations for building embankments – the presumed increase in crop production that they would enable – appears to have been a false presumption. These results indicate that a full cost–benefit analysis of dismantling embankments, probably gradually rather than all at once, is called for. This would involve many factors not examined here, such as, on the one hand, the cost of alternative infrastructure to raise buildings, roads and other infrastructure that have been developed under the presumed protection of existing embankments[8] and, on the other hand, the inevitably increasing dangers of breaches and costs of embankment maintenance as river beds confined within embankments rise with siltation, as well as the flooding induced by embankments that block natural drainage during the monsoon. One of the lessons from this study is that, if embankments are replaced by dispersed infrastructure, then apart from obvious measures like raising buildings on stilts and digging new channels for river flow, the replacement should include the social infrastructure of employment generation or other social security during the monsoon for areas that will face increased flooding.

It is possible that data from a larger sample of villages over a longer period of time would overturn these conclusions. Until and unless such data emerge, the burden of proof is now on those who claim that embankments in this region of the world have raised welfare.

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[8] The Government of Bihar estimated the cost of existing embankment maintenance to be 500,000 rupees per kilometre, or about 1.7 billion rupees for the 3,430 kilometres of embankments in the state (Anonymous, undated). At a 5% discount rate, the present value of this is 34 billion rupees, a lot less than the 150 billion rupee damage estimate of the 2008 Kosi flood. Unfortunately, given the record of breaches in the last few decades, it is unclear that this sum, or anything like it, would be sufficient to buy safety.

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