Early Flood Events and Their Impact on Poor Smallholders in Rice-Based Floodplain Farming Systems in Bangladesh

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Abstract:

Floodplain agriculture in Bangladesh is characterised by smallholders operating marginal parcels. Early flood arrival may damage the standing winter rice crop. Using data from a micro area, we investigate: (a) patterns of damage caused by one and two week early floods, (b) whether poorer households stand more exposed to such risks, and (c) opportunities for risk reduction. The methodology employs GIS methods combined with simple water-yield damage parameters. Results indicate that lower elevation plots are inundated by floods arriving even a week or two early, and significant crop loss may result. The factors causing late harvesting, leading to early flood risk exposure, are (i) preceding winter rice with mustard, and (ii) using older, long duration, varieties. Planting mustard (to finance inputs for the following rice crop) delays planting of winter rice sufficiently to expose it to flood damage risk. Poorer classes are found to operate disproportionately large amounts of lower elevation land, which exposes them more to early flood risk. We find that 'squeezing' the crop calendar is best achieved within the rice calendar itself. Smallholders are using the earlier generation of rice varieties, while shorter duration varieties providing better yields are available. Thus available technology is failing to reach vulnerable smallholders.

Keywords: Early flood risk, Bangladesh, Floodplain, Rice.

1. Introduction

The management of flood risk in Bangladesh has been largely focussed on control of water levels in the peak flood season. This focus is not surprising, since extreme flood events such as in July-October 1998 due to overspill from the major rivers cause widespread loss of life, habitat and agricultural livelihoods. In some parts of the country, however, even in ‘normal’ flood years (characterised by typical or average flood depths on the plains), early local rainfall and/or early discharge of floodwaters from upstream catchments can cause damage to standing Rabi (winter/dry season) or Kharif-1 (early flood season) crops prior to their harvest. Much of floodplain agriculture in Bangladesh is characterised by smallholders operating and depending on very small holdings of land, and therefore scope for diversification of such risks is correspondingly low. Since early flooding can often wipe out a crop completely, understanding contributory factors and devising solutions to mitigate early flood risk is of great importance.
Where overbank flooding from main river channels is the principal source of early flood risk, structural means of flood control, such as the use of submersible embankments or sluice gate management practices can be effectively employed.

In many areas, however, early floods may arise from early local precipitation events rather than overbank river flooding, and structural methods may not prove effective in early flood risk control. In such situations, it is important to understand the entire crop cycle in order to ascertain what factors may determine exposure to early flood risk and what non-structural means are available to reduce exposure. In this paper, we use primary data on cropping, water depths and socio-economic variables at the plot level in a floodplain micro area in North-central Bangladesh in an effort to seek answers to the early flood risk problem posed.

2. Flood and Crop Seasons

The timing of typical *Kharif-1* and *Rabi* crop schedules and flood timings for the Northcentral region are illustrated in Table I below. Overbank river flooding typically commences between mid-June and early July, usually after the harvest of the Boro rice crop. With the lower lands given over to Boro, if the flood arrival is even a week or two early, it has the potential to damage those Boro areas that remain unharvested.

Table I: Flood and Kharif-1/Rabi calendar for Northcentral Bangladesh

Seasons/Crops/Flooding	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kharif-1 Season			←	—	—	—	—	→				
Kharif-2 Season						←	—	—	—	—	—	→
Rabi Season	—	—	—	—	—	→					←	—
Aus Rice				←	—	—	—	→				
Jute			←	—	—	—	—	→				
Aman Rice						←	—	—	—	—	→	
Boro Rice	—	—	—	—	—	→						←
Normal Flood						←	⋯	⋯	⋯	→		
Early Flood					←	⋯	⋯	⋯	⋯	→		

With the rapid replacement of the *Kharif-1* season with an extended *Rabi* season, the impact of early flood events is thus felt most by the Boro crop. While *Aman* crop damage due to heavy flooding in the peak flood season can be sometimes mitigated by re-transplanting, early flood arrival often means considerable damage to Boro. Early floods are most characteristic of the *haor* regions of Northeast Bangladesh, but Boro crop damage due to early flooding is not exclusive to the northeast. In a recent research project on floodplain livelihoods (Barr, 2000), a problem census conducted at the Charan *beel* site in northcentral Bangladesh revealed that Boro damage in low elevation lands was perceived as a significant problem. With an increasingly '*boro*-centric' agricultural economy, the implications of damage to the *Boro* crop can be substantial.

In what follows, we simulate the arrival of an early flood in the Charan beel area, using Geographic Information System (GIS) methods and data from the research project (Barr, 2000) mentioned above. By simulating the effect of an early flood arrival, and combining the simulated inundation levels with plot level cropping-pattern, plant growth-stage information and crop damage factors, rough plot-level crop damage estimates are calculated. These estimates are combined with socio-economic information to provide insights into the vulnerability of poorer households to early flood risk. The current choice of crop varieties is then examined in conjunction with information on available alternatives, to determine whether there is scope for managing early flood risk by using shorter-duration alternatives.

3. The Charan beel and floodplain Area: Background

Charan *beel* (a shallow saucer-like floodplain depression), is situated in Tangail district in Northeast Bangladesh. It lies between two distinct river systems, the Dhaleswari and the Bangshi. The *beel* comprises a small perennial waterbody of 44.5 ha at its centre, surrounded by arable land that is seasonally flooded as the waterbody expands to cover 394 ha during the monsoon. Settlements are located on higher land around the margins of the depression. The earlier part of the *Rabi* season at Charan experiences very little rainfall and cropping is irrigation dependent.

Following a reconnaissance social survey that served as a mini-census to provide a basis for social stratification, a sample of households from three villages around the *beel* was selected by the project. Stratification was on the basis of landholding, which is recognised as a reliable proxy for wealth in rural Bangladesh. The stratification is presented in Table II below; this is based on categories used by the Bangladesh Bureau of Statistics in the Agricultural Census and other reports. From this larger stratified sample, a sub-sample of 210 households was selected for more detailed study, with 30 households belonging to each stratum. Basic socio-economic data were collected for each household in the subsample, including information on landholding.

Table II: Classification of households on the basis of land-holding

Stratum	Land owned (acres)	Socio-economic category
1.	<0.049	Landless - Categories I & II
2.	0.05 - 0.49	Landless - Category III
3.	0.5 - 0.99	Marginal
4.	1.0 - 2.49	Small
5.	2.5 - 4.99	Medium – I
6.	5.0 - 7.49	Medium – II
7.	>7.5	Large

The project also collected data on a set of biophysical variables over 1997-98. These included flood depth measurements and areal extent of flood spread at approximately monthly intervals during the year, and an inventory of plots belonging to the sample households. A subset of plots was chosen for crop pattern monitoring, recording crops grown during the year, and some basic information on crop growth stages at discrete points in time (a recording taken once a month). This and other information was gathered together in a project GIS, with linkages established between households and plots[1]. The research reported here utilizes these data in a modelling exercise designed to throw light on the early flood risk problem.

4. Methodology

(i) Sample selection: In order to analyse the effects of an early flood, it is necessary to have a basic understanding of the cropping system for the entire year. For example, some Boro plots may be harvested in April, while others not until May, with the latter plots being more susceptible to damage from early flooding. The reasons for this asymmetry in harvesting times may lie in the use of the particular plots in the previous season or in the flooding status of the plot in previous months. For instance, allowing the plot to lie fallow prior to the Boro crop allows for earlier transplanting and thereby earlier harvesting.

[1] The intersection between plots and households is not complete. In other words, some plots cannot be linked to household-level socio-economic information, and for some plots owned by the sample households, cropping pattern information is not available. However, there is a significant enough intersection to make our analysis possible.

Alternatively, some plots may drain too late for an early *Rabi* crop to be squeezed in before the Boro, which in turn encourages earlier transplanting of the Boro. Knowledge of the transplanting date is important for this analysis, and so plots without sufficient information were dropped from the analysis. The final sample of plots retained comprised 20 very low (VL), 38 low (L), 72 medium low (ML), and 107 medium high (MH) plots[2], 237 in all.

(ii) Establishing crop damage parameters: A literature search was undertaken to establish damage parameters for the Boro crop in relation to inundation levels. The existing literature was by-and-large found to be based on experimental studies, with results conditional on a number of control factors such as age of the seedlings at the time of transplanting, temperature regimes prevailing during the growing season, etc. No data on such factors are available for this site[3]. In the end, simple damage parameters established by the Master Plan Organisation (MPO) of Bangladesh were found to be the most synthetic and most easily integrable with the rest of the analysis. These parameters have been used in several previous studies of flood impacts on agriculture in Bangladesh. Since the MPO table only provides information at discrete growth stages and water depths, linear interpolations were established between these discrete data points so that damage estimates could be more continuous with respect to water levels.

(iii) Computing baseline damages: The water heights for the last month prior to harvest in each of the 237 plots were analysed to establish whether the levels were high enough at any time to potentially cause damage to the crop. This had to be done for each plot individually due to the differences in harvesting dates.

(iv) Simulating early flood arrival and crop damages: The project GIS stores empirical information on flood spread at the plot level for the period August 1997 to August 1998. A 'water theme time shift' GIS tool can de-couple the flood data, thereby lagging or advancing the flood in relation to production activities at the plot level. Two early flood onset scenarios were thus simulated – flood onset one and two weeks early respectively[4]. The water heights on individual plots were again used in conjunction with the crop damage parameters to establish crop damage for the early flood scenarios, as in (iv).

(v) Livelihoods and poverty dimensions:

The design of the GIS gives the ability to interrogate it about the impact of various management scenarios on floodplain residents as a group, and disaggregated according to different wealth (land-ownership) classes. By combining the analysis of elevation-specific early flooding risk with socio-economic information from the GIS on elevation-specific land-ownership by different wealth classes, it is possible to inquire whether the effects of early flood onset are felt uniformly across the socio-economic classes. Thus the hypotheses of linkages between poverty and increased vulnerability to environmental risks in the livelihoods of the poorest classes can be tested.

(vi) Examining the role of short-duration varieties: Finally, in seeking possible management interventions that might significantly reduce the risk posed by early floods, the question is posed as to whether the use of

[2] 'High' plots are not considered here since they are flood-free by definition.

[3] At any rate, the objective of this modelling exercise is not to establish such biophysical precision, but rather to generate broader lessons and to capture the bigger picture.

[4] The probability of floods arriving earlier than two weeks is quite low, and hence this analysis restricts itself to one and two week early floods.

alternative short-duration varieties in place of the existing varieties would enable harvests early enough to avoid flood damage. This is done simply by comparing varieties currently in use with available alternatives.

5. Cropping patterns at Charan beel

As is the trend in several parts of Bangladesh, the traditional *Aus-Aman-Boro* system, corresponding to the *Kharif-1 – Kharif-2 – Rabi* seasons, has been replaced by a *Kharif-rabi-1-rabi-2* pattern in Charan. *Aman* is broadcast or transplanted with the start of the flood in July, and is harvested with the beginning of the drawdown in mid-October//November. The extended *Rabi* season commences after the drawdown, with a short fallow in some plots and a short *Rabi* crop such as mustard in others. Boro is omnipresent, and is transplanted between December and early March, coming off the land in April/May, prior to the arrival of the next year's floods in June.

The elevation-specific breakdown of major cropping patterns in the sample plots is shown in Table III below. The table clearly illustrates that elevation plays a significant role in cropping pattern choice at Charan. Very low plots are completely given over to *Rabi* season production, being too deeply flooded for *Aman* production in the *Kharif* season. 55% of the VL plots are devoted to a single Boro crop, while the other 45% manage to include a short mustard crop prior to boro. Mustard is a low-input cash crop that grows quickly, the proceeds from which are used by farmers to finance the input-intensive Boro crop. It is sown right after flood drawdown using residual soil moisture and minimal inputs. Subsequent to the mustard harvest, the land will be soaked and puddled in advance of transplanting.

The increase in cropping intensity in response to elevation increases is clearly seen. Low plots are still dominated by fallow/fallow/Boro and fallow/mustard/Boro rotations, but some *Aman* production is also present. The incidence of single Boro cropping declines sharply as elevation increases. ML and MH plots are predominantly double or triple-cropped. Transplanted *Aman* is more easily damaged by flooding than broadcast *Aman*, and hence is observed only in MH land.

*Table III: Cropping patterns on sample plots at Charan beel**

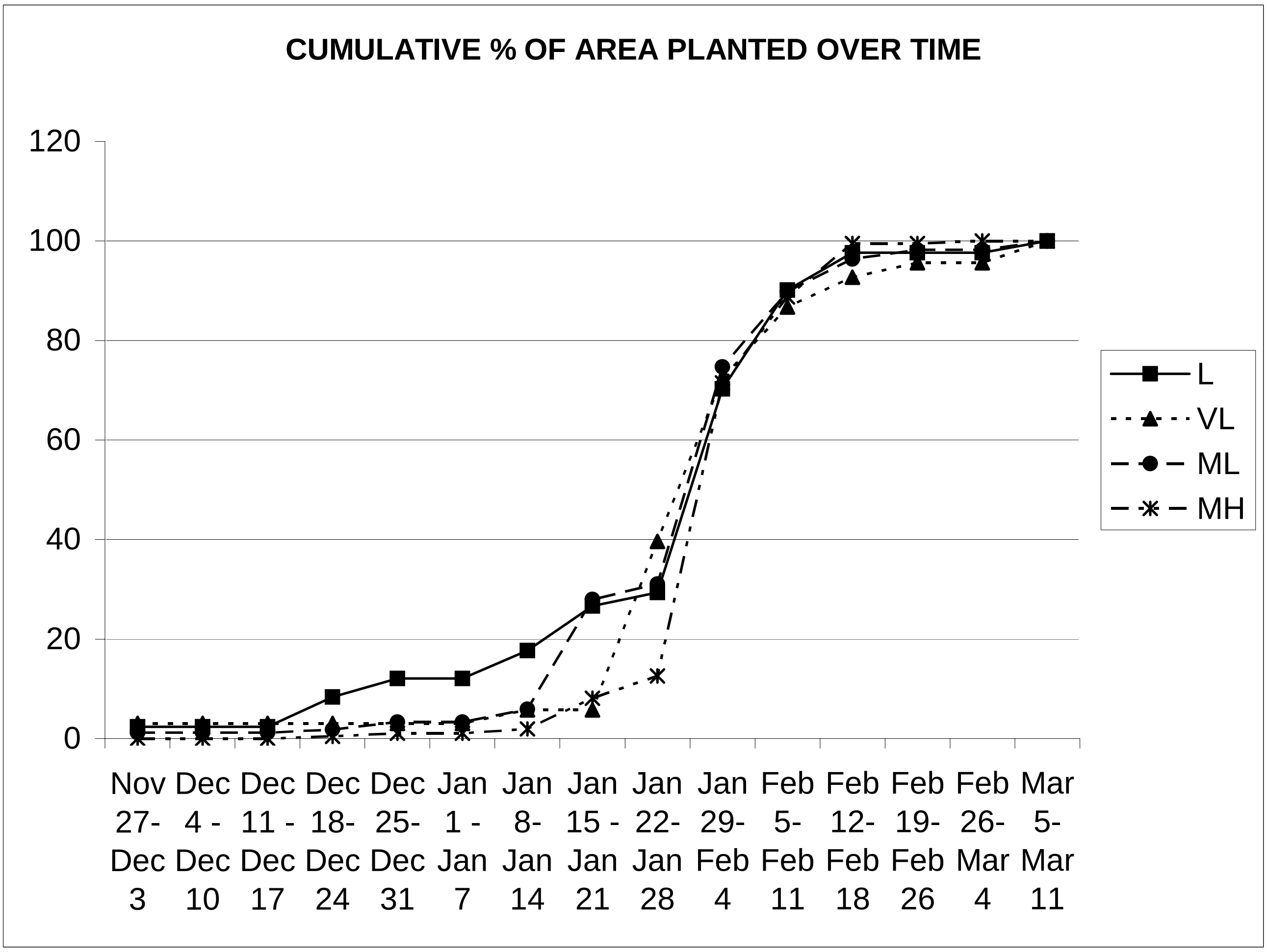
Cropping Pattern	**VL** (20 plots)	**L** (38 plots)	**ML** (72 plots)	**MH** (107 pl)	**Total** (237 pl)
Fallow/Fallow/Boro	55.00%	42.11%	23.61%	20.56%	27.85%
Fallow/Mustard/Boro	45.00%	39.47%	59.72%	39.25%	45.99%
Fallow/BAman/Boro	0.00%	0.00%	0.00%	4.67%	2.11%
BAman/Fallow/Boro	0.00%	7.89%	4.17%	1.87%	3.37%
BAman/Mustard/Boro	0.00%	10.53%	11.11%	19.63%	13.92%
Mixed/Mustard/Boro	0.00%	0.00%	1.39%	0.93%	0.84%
TAman/Fallow/Boro	0.00%	0.00%	0.00%	11.22%	5.06%
TAman/Mustard/Boro	0.00%	0.00%	0.00%	1.87%	0.84%
					100.00%

* The sequence used here is based on the flood year (starting in June) rather than the calendar year.

As cropping intensity increases, flexibility in timing the planting of the Boro crop is inevitably reduced. Early transplanting of the Boro crop, in December or early January, would enable a harvest in late April or early May. Where a mustard crop is grown after drawdown and prior to the Boro, however, the transplanting of Boro may be pushed into February, resulting in a later harvest and greater exposure to early flood risk. Currently this is a trade-off that farmers need to factor into their decision making: Option 1 is a mustard crop, followed by a *Boro* crop**.** The mustard is grown as a cash crop, the seeds can be sold to millers for mustard oil production; the cash thus obtained is immediately invested into the inputs for the proceeding *Boro* crop. As the proceeding analysis shows, depending on land elevation, there is risk of losing some of the crop due to flood damage. Option 2 is a *Boro* crop alone. The more flexible timings permitted by a single *Boro* crop mean that there should be negligible flood damage risk, however the crop is also more expensive (less profitable) as greater levels of credit will be needed to supply the necessary inputs.

Figure 1 below summarises the planting dates for our sample plots by land elevation categories.

Figure 1: Timing of Boro transplanting, by elevation classes at Charan beel



As seen from the figure, higher proportions of area are transplanted later in the *Rabi* calendar as land elevation increases. About 10% of the low land is planted by end-December, while there is very little planting in December in the other land types. The planted proportion for Medium High lands is only a little over 10% until late January. In the last week of January and the first week of February, there is a rapid surge in planting across land types. Planting continues through February, and is more or less complete by the end of the month, except for a few plots that are planted in early March.

Very low lands appear somewhat anomalous to this pattern, with little planting occurring until the third week of January. Two possible explanations exist for this: first, being immediately adjacent to the receding *beel*, VL lands drain slower than average and are the last to be exposed if they are even ever completely exposed. Planting may be delayed due to this factor, even if the land was previously fallow. Second, VL lands are more likely than other land types to grow local varieties of Boro. Local varieties are usually of short enough duration to be harvested well before flood arrival, even if planted late, or have some ability to elongate to cope with some early onset flooding. They are however low yielding.

Table IV below shows the temporal distribution of harvest according to land type.

Corresponding to earlier planting of L lands compared to other land types, a greater proportion of L lands are also harvested earlier. Boro crops on ML and MH lands, being least susceptible to flood damage, are more likely to be harvested late in the summer, with about 66% of the crop on these land types still standing on 20 May.

Across land-types, the bulk of harvest occurs in May, especially in the last week. By the first week of June, all plots have been harvested.

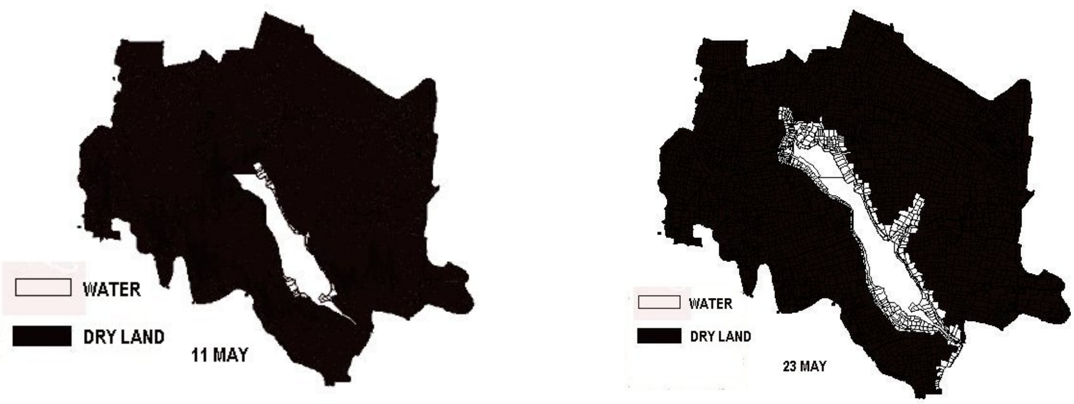
Table IV: Harvest times by land elevation at Charan

Harvest Dates	VL	L	ML	MH	Grand Total
25-27Apr-98	10%	17.53%	5.5%	1.38%	5.9%
04-06 May-98	0.00%	0.00%	5.5%	1.13%	2.18%
06-08 May-98	40%	9.15%	4.16%	1.26%	6.65%
11-13 May-98	0.00%	0.00%	0.00%	0.82%	0.37%
16-18 May-98	0.05%	33.89%	20.83%	28.61%	24.68%
22-24-May-98	45%	34.40%	56.9%	59.62%	53.5%
31 May - 02-Jun-98	0.00%	5.03%	6.94%	7.17%	6.15%
Grand Total	100.00%	100.00%	100.00%	100.00%	100.00%

6. Flood Spread at Charan Beel

Over the dry-season, the Charan beel area steadily dries up until only the small area of the perennial beel remains inundated. Thus there is a temporal decline in flooded areas as well as depths from drawdown onwards until the start of May, with much of the area drying up early in the winter. The first panel of Figure 2 shows the flood extent on 11 May, when the water spread is at its lowest[5]. The second panel, for 23 May[6], shows that the water levels have already started gradually increasing in the 3rd week of May, and the lowest plots close to the perennial part of the beel have been inundated.

Figure 2: Water levels at Charan Beel on 11 May and 23 May, 1998

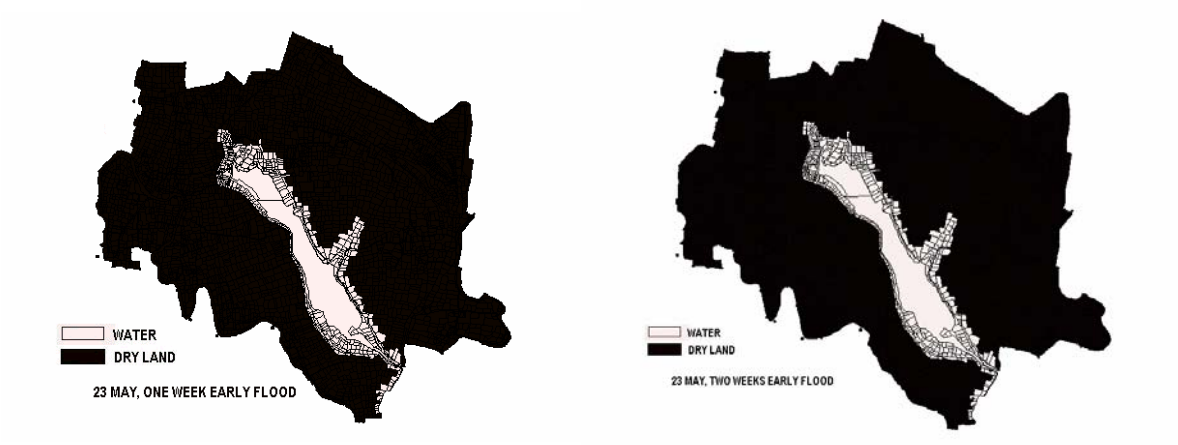


[5] The water cover/depth stays at this minimum level for well over a month.

[6] 23 May is chosen for the illustration of our early flood arrival simulation here because a good proportion of the Boro crop in the area is harvested in 22-24 May, as seen before.

The water spread results from the GIS-based counterfactual simulations are illustrated (as on one particular day, 23 May) in Figures 2 and 3, the first where the flood arrives one week early and the second where it arrives two weeks early. As can be seen, the *areal extent* of the flood spread seems to remain more or less constant at Charan at this critical period even when the flood arrives a week or two early.

Figure 3: Water cover at Charan on 23 May, one and two week early floods.



It would be misleading, however, to conclude from this that early flood arrival does not pose a threat to the Boro crop. Table V below presents the average water depth on the sample plots for the baseline of 23 May, compared to when the flood arrives 1 and 2 weeks early. Medium high plots are seen to stay flood-free even with a two-week early arrival of floods. VL plots on the other extreme, are seen to be very vulnerable to even a short advance in flood timing. The average flooding on VL plots on 23 May when the flood arrives just a week early, is 1.36 metres, a depth that is enough to almost completely destroy any standing crop.

Table V: Average water heights (metres) for sample plots by land elevation

	VL	L	ML	MH	All Plots
Average of 23May98 water height	0.026	0.009	0	0	0.0021
Average of 23May98, 1 wk early	1.36	0.271	0	0	0.15
Average of 23May98, 2 wks early	2.33	1.13	0.18	0	0.43

7. Estimates of crop damage due to early flooding

As the estimates presented in Table VI show, 55% of the VL plots suffer some form of damage even from a one week early flood. Significantly, when the damage occurs, it is likely to be substantial. 40% of the VL plots are almost completely damaged by a one week early flood. Evidently, the low plots flood rapidly and deeply, as was previously indicated in Table V. The L plots on the other hand, are largely unaffected by a 1 week early flood. A two week early flood would however cause significant damage to about a quarter of the low land Boro crop. The ML and MH plots remain largely unaffected even by a two week early flood.

Table VI: Crop damage estimates by land elevation

Very Low Land Crop Damage: % of Plots in Damage Categories					
	No damage	**20% to 40%**	**40% to 60%**	**60% to 80%**	**80% or higher**
Baseline Flooding	100%	0%	0%	0%	0%
1 Week Early	55%	0%	5%	0%	40%
2 Weeks Early	50%	0%	0%	0%	50%

Low Land Crop Damage: % of Plots in Damage Categories					
	No damage	**20% to 40%**	**40% to 60%**	**60% to 80%**	**80% or higher**
Baseline Flooding	100%	0%	0%	0%	0%
1 Week Early	92%	3%	0%	0%	5%
2 Weeks Early	61%	3%	11%	0%	26%

Medium Low Land Crop Damage: % of Plots in Damage Categories					
	No damage	**20% to 40%**	**40% to 60%**	**60% to 80%**	**80% or higher**
Baseline Flooding	100%	0%	0%	0%	0%
1 Week Early	100%	0%	0%	0%	0%
2 Weeks Early	90%	3%	1%	1%	5%

Medium High Land Crop Damage: % of Plots in Damage Categories					
	No damage	**20% to 40%**	**40% to 60%**	**60% to 80%**	**80% or higher**
Baseline Flooding	100%	0%	0%	0%	0%
1 Week Early	100%	0%	0%	0%	0%
2 Weeks Early	100%	0%	0%	0%	0%

With a one-week early flood being a high-probability event, the VL lands, and to a lesser extent, L lands, are seen to be very exposed to early flood damage at Charan beel. The aggregate estimates, however, do not provide a clear idea of whether there is any specific pattern to the damage. A profile of damaged vs undamaged plots could provide a better idea. Since the sample numbers of VL plots are small, it is instructive to look at information at the plot level. We present such information in Table VII below[7].

[7] Note that varietal information was not available for all boro-cropped plots in the database.

Table VII: Plot-level damage information for VL plots

			VL: Undamaged Plots					
Plot ID	**Area (m^2)**	**Variety**	**Planting Date**	**Harvest Date**	**Pattern***	**Baseline Damage**	**1 wk early**	**2 wks early**
10937	1123	BR 11	03-Dec-97	06-08-May-98	F/F/B	0	0	0
10938	1305		24-Jan-98	06-08-May-98	F/F/B	0	0	0
22173	1409		24-Jan-98	06-08-May-98	F/F/B	0	0	0
22174	1334		24-Jan-98	06-08-May-98	F/F/B	0	0	0
22175	1681		24-Jan-98	06-08-May-98	F/F/B	0	0	0
22176	2389		24-Jan-98	06-08-May-98	F/F/B	0	0	0
10345	532.6		07-Feb-98	06-08-May-98	F/F/B	0	0	0
22110	507.5	Local	18-Feb-98	25-27-Apr-97	F/F/B	0	0	0
22177	1696	Local	18-Feb-98	25-27-Apr-97	F/F/B	0	0	0
22121	1616	Kuinal (Local)	05-Mar-98	06-08-May-98	F/F/B	0	0	0

			VL: Damaged Plots					
Plot ID	**Area (m^2)**	**Variety**	**Planting Date**	**Harvest Date**	**Pattern***	**Baseline Damage**	**1 wk early**	**2 wks early**
20537	1016	IR 8	14-Jan-98	22-24-May-98	F/F/B	0	80-100%	80-100%
21659	1970		24-Jan-98	22-24-May-98	F/M/B	0	80-100%	80-100%
21661	2341		24-Jan-98	22-24-May-98	F/M/B	0	80-100%	80-100%
22027	3614	IR 8	01-Feb-98	22-24-May-98	F/M/B	0	80-100%	80-100%
21948	1921	IR 8	03-Feb-98	22-24-May-98	F/M/B	0	42%	80-100%
22045	2781	Sharkari/BR 16	03-Feb-98	22-24-May-98	F/M/B	0	80-100%	80-100%
22046	3700	Kaora	04-Feb-98	22-24-May-98	F/M/B	0	80-100%	80-100%
22004	3009	Sharkari/BR 16	05-Feb-98	16-18-May-98	F/M/B	0	0	80-100%
22050	1728	Sharkari/BR 16	05-Feb-98	22-24-May-98	F/M/B	0	80-100%	80-100%
22002	1051		19-Feb-98	22-24-May-98	F/M/B	0	80-100%	80-100%

F=Fallow, M=Mustard, B=Boro

The plot-level information for VL lands is quite revealing. The plots undamaged by one and two week early floods are exclusively single-cropped with Boro. The majority of these are planted before January 25, and are harvested around the 7th of May, well before even an early flood arrival. The exceptions that are planted in February are local varieties with short durations, which are still able to come off the land ahead of the early flood danger time zone. This is in marked contrast to the damaged plots, where almost all plots are double-cropped with mustard preceding boro. This often pushes planting time into early February, and inevitably delays harvest until the last week of May. At the baseline, in a normal flood year, harvest at this time is in advance of flooding. But when the flood arrives even a week early, damage to these crops is in excess of 80%. Note also that the damaged VL plots are mostly planted to the older generation of long-duration HYV Boro such as IR8.[8]

8. Vulnerability to early flooding by socio-economic category

Given the overall orientation of this study, it is particularly important to determine whether there is any empirical evidence that the poorer classes are more exposed to early flood risk than more well-to-do classes. One way of approaching this would be to take the *particular* set of 'damaged' vs 'undamaged' VL and L plots above, and determine empirically if the damaged ones are more likely to belong to poorer households or not. This did not prove to be possible, however, because of the lack of a complete link between cropping and household information in the dataset, as discussed above. For some of the plots in the above set, ownership data were not available. Hence, a more general question is posed: given that VL and L lands are by-and-large found to be the only types exposed to early flood risk, is there evidence that these lands types (in *general*) are more likely to be owned by poorer households? Additionally, typically what proportion of the land portfolio of poorer households is made up of VL and L lands? The dataset from Charan contains complete plot ownership records of a household sub-sample stratified by land-ownership classes that enables this analysis. In order to avoid any potential distortions arising from small samples, the 7 socioeconomic classes in Table II were collapsed into 4 for this analysis: (almost) landless (<0.5 acres), marginal and small (0.5 to 2.5 acres), medium (2.5 to 7.5 acres), and large (>7.5 acres).

The distribution of land ownership by social class across land elevations is shown in Table VIII. High land comprises over 50% of the total land area held in the sample. This sample value is generally reflective of elevations around Charan beel, where lower lands are concentrated around the beel, with elevations generally increasing as distance from beel increases, and households operating lands in a large surrounding area. The actual area of VL and L land is relatively small (about 22% of total), and this skewness in the distribution of elevations implies that there is a natural hedge available against early flood risk at Charan. However, if particular classes are found to hold significantly disproportionate amounts of L & VL land, the hedge available to them would be correspondingly low.

[8] Similar plot-by-plot analysis for L lands is not presented due to space constraints. Although the pattern for L plots does not turn out to be as clear cut as for VL plots, as a general rule, all plots planted by the last week of January appear to be flood risk-free, and as for VL plots where mustard precedes boro, there is an increased chance of damage.

Table VIII: Aggregate land ownership by socio-economic class (acres)

SECLASS	VL	L	ML	MH	H	Grand Total	L&VL as % Of total
Landless	1861	358	287	989	3713	7208	30
Marginal & Small	3895	443	1391	4361	8096	18186	23
Medium	1073	481	760	1649	4949	8912	17
Large	0	0	70	149	1493	1712	0
Total	6829 (19%)*	1282 (3.5%)*	2508 (7%)*	7148 (20%)*	18251 (51%)*	36018	

* % of grand total (36018 acres)

The last column in Table VIII shows the % of VL and L land area in total land owned by each category. There does appear to be a connection between socio-economic class and the distribution of land-ownership by elevation classes. The nearly landless own disproportionate amounts of land potentially vulnerable to early flooding (30%) compared to the average (22.5%). The proportion of L & VL land in the portfolio of marginal & small and medium classes is roughly similar to the average. The large farmers, however, own practically no VL and L lands, their portfolios almost exclusively comprised the flood-free MH and H land. This empirical connection points to elevation makeup being a further inequalising factor in the floodplains of Bangladesh. The gulf in the wealth status of the landless and the large farmers is already substantial, with a large farmer owning over fifteen times the land owned by a nearly landless floodplain dweller. But with the largest farmers owning practically no low land in Charan, and the poorest owning disproportionate amounts, the riskiness of low land production adds to the vulnerability gulf between large and smallholders.

9. Short-duration varieties

The early floods experienced in Charan beel and other such sites in the North-Central area are predominantly due to early local precipitation events, which cannot be controlled by the construction of submersible embankments. An alternative way to manage this risk is by adjusting the cropping calendar during the year so that the Boro crop can be harvested from a week to two weeks early. It can be seen from the simulation results for VL plots in Table VII that the bulk of the early flood damage happens when plots harvested during the period 22-24 May period are visited by early floods. At the baseline itself, *i.e.*, in the period 22-24 May, water levels are not high enough to cause damage to any of the plots. Thus if these plots were harvested even a week earlier, *i.e.*, in the 15-17 May period, a one-week early flood would cause no damage whatsoever to these plots. In the case of the L plots, the risk of damage is principally from *two*-week early floods, again predominantly on plots harvested around 22-24 May. As before, a one-week earlier harvest would eliminate damage from even the relatively low-probability two-week early flood.

Opportunities to adjust the cropping calendar in order to achieve an earlier Boro harvest potentially exist throughout the crop year. However, as seen from the simulation tables, damage is largely restricted to VL and L plots that are at most double-cropped, involving no *Aman* production. Thus the *Kharif* season does not seem to offer an opportunity to advance the calendar. Mustard is almost exclusively the pre-Boro crop in double-cropped plots. As seen before in the case of VL plots, it is the set of plots double-cropped with mustard and Boro that stand most exposed to early flood damage. Therefore it is worth investigating whether opportunities exist to squeeze the crop calendar in the early *Rabi* period. However, an investigation of the mustard varietal information in the database revealed that a local mustard variety, Tori-7 was predominant in the Charan area. Tori-7 is a low-yielding variety, but can be grown in 70-80 days, while all the higher-yielding varieties take upwards of 90 days. Thus, far from providing opportunities to shorten the cropping calendar, the available alternatives in fact would tend to elongate it.

The opportunities for contraction of the cropping calendar then seem restricted to the Boro crop itself. A look at the varietal composition in Table VII for VL land reveals that there does indeed appear to be scope for mitigating early flood risk by using shorter-duration Boro varieties. Boro grown on VL and L plots at Charan is primarily of three varieties:IR8, or ‘IRRI rice’, BR16, and BR11. Table IX below presents basic information on the growth duration (including seedbed period) and experimental grain yields for these varieties and some potential replacement varieties. The widespread prevalence of IR8 in lowland plots in Charan is somewhat surprising, since it is a variety dating back to the late 1960’s which has played a significant role in the green revolution, but has since been widely supplanted by improved varieties developed later. Quite possibly, its strong presence at Charan points to inadequate extension services in the area. With a growth duration of 170 days, IR8 is of longer duration than most available alternatives. The other two prominent higher-yielding varieties observed at Charan, BR11 and BR16, also have relatively long durations (165 days). At least two attractive alternatives exist that can provide comparable yields and reduced durations in the field. BR 26 and BR28 reduce the field duration by over two weeks compared to the existing varieties, and do not suffer a significant disadvantage in terms of yields. BR29 enables a slightly earlier harvest compared to IR8, BR11 and BR16, and significantly higher yields.

Table IX: Growth duration and yield potential of some important Boro varieties in Bangladesh

Variety	Growth duration (days)	Grain yield (t/ha)
BR 11*	165	6
BR 14	160	6
BR16	165	6
BR 26**	145	5.8
BRRIdhan 28	140	5.8
BRRIdhan 29	160	5
BRRIdhan 36	140	5.5
IR8	170	5.5

*Originally released as *Aman* variety, but also grown as boro.

**Originally released as *Aus* variety, but also grown as boro.

Sources: Jashim and Chowdhury (2001); Salam (1992), FAP20 (2000), BRRI (1997)

It is important to note that the experimental results reported in Table IX can differ significantly from what is achieved on farmer's fields. However, the available evidence points towards significant advantages in moving away from the traditional higher yielding varieties such as IR8, as well as the older generation of BRRI-developed higher-yielding varieties such as BR11, towards the new generation of shorter-duration, higher-yielding varieties. Thus our evidence from Charan shows that early flooding is not a problem that will require any new investments in technology. Requisite technology in the form of a new generation of shorter duration *Boro* varieties has been available for some time now, but is apparently failing to reach this group. A programme of farmer-based research on using existing shorter duration Boro varieties could go some way in ameliorating this situation.

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