MODELING THROUGH GEOGRAPHICAL INFORMATION SYSTEMS (GIS) OF THE IMPACT OF HYDROLOGICAL CHANGES IN A FLOOD PLAIN ON FISHERIES, AGRICULTURE AND INCOME GENERATION

AN EXAMPLE OF BANGLADESH

by

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INTRODUCTION

One of the major questions during a number of studies related to flood control during the Flood Action Plan in Bangladesh was ***"What will be the impact of the proposed interventions on fisheries".***

Reduction of the floodplain will result in direct and indirect losses. The direct loss is a reduction in fishing area producing a certain quantity of fish per year. Indirect losses are the result of the reduction in spawning and nursing area, impacting the whole fish community. In the past, several methods were used for the impact of flood control on fisheries:

In the '80s, the average production of the floodplain was multiplied with the total floodplain area in order to estimate the floodplain fisheries production. Fisheries losses were estimated by multiplying the floodplain area lost with the average floodplain production.

Water depth and water quality data were used in the Morpho Edaphic Index in order predict/estimate fisheries production. However, this method proved to be unreliable.
In several FAP projects (FAP 12, FAP 5.2 & FAP 3) the methodology was improved and different habitats such as Beel, floodplain, khals and rivers were considered. The production levels in most cases were obtained from secondary data.

The Compartmentalization Pilot Project in Bangladesh (de Graaf et al 2000) started to link habitat related fish production figures with hydrological models in order to predict the fisheries production for different water management scenarios in 1992 (CPP, 1992). Over the years this methodology was improved through:

- a rigorous, habitat-specific monitoring programme of FAP 17 (1992-1994) and CPP (1992-2000);
- development of hydrological models;
- the incorporation of Geographical Information Systems for the determination of the different habitat areas.

Over the years the model of CPP improved, became more accurate, and more parameters were added, especially socio-economic ones. The model, little by little, evolved towards a decision support model or a preliminary stage of “blue accounting” (EGIS, 2000) for different water management options in CPP.

A multidisciplinary and integrated approach to planning for natural resource use, for which such models are essential, is getting more attention in Bangladesh. Therefore in this paper detailed information is provided on model made for CPP. This to explain the basic principles, and to provide the basis for further development and use of this model.

THE CPP PROJECT AREA

The Compartmentalisation Pilot Project (CPP, also called FAP 20), that started in 1991, is a water management project situated on the East bank of the Jamuna river, with Tangail Town in its centre (Figure 1).

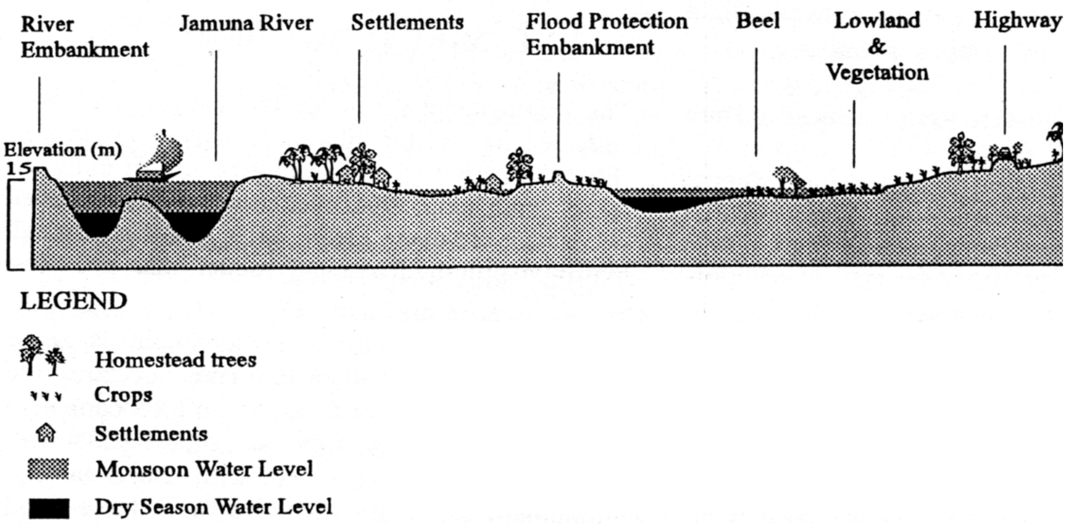
Figure 1: The Compartmentalisation Pilot Project

The project area is situated in the Young Brahmaputra Flood Plain. The natural drainage pattern is away from the Brahmaputra (Jamuna) and Dhaleswari rivers towards low-lying land in the southeast. Land elevation varies between 14 and 7 m+PWD. Large depressions (Beels) are found throughout the project area. Although the overall topography is rather flat, local landscapes are very diverse. Local differences are due to the following features:

- Floodwater courses of natural rivers
- Terraces and ridges of different levels, due to large extensions of the old and active floodplains
- Artificially levelled homesteads
- Roads, flood protection, embankments, etc.
- Different levels of cropping fields, which is a sequence of small terraces built for water management.

A typical cross-section profile of the study area from west to east is presented in Figure 2.

Figure 2: A typical cross section of the CPP area from west to east (source: EGIS)



To explain the principle and the inputs/outputs of the model, it was applied to a water management scenario whereby the water level in the Lohajang River during the monsoon is maintained at a level in the range of 11.0 –10.5 m +PWD.

THE CPP MODEL

The CPP model works with quantifiable parameters, i.e. kg, Tk, labour days, ha, etc., only, and consists of the following five modules:

1. A hydrological module, which translates target level into temporal and spatial flood patterns
2. A fisheries module, which calculates the fish catches for the different target levels
3. An agriculture module, which calculates the agricultural production for the different target levels
4. An economic module, which calculates the economic returns for the different target levels
5. A socio-economic module, which provides information on socio-economics and distribution of profits and losses.

The model works with the assumption of a constant fishing effort and does not take into account the impacts of over-fishing due to increased fishing effort or increased population growth. The rainfall and upstream hydrology of the season 1993/92 was chosen as major input for the model because pre-project data on fisheries and agriculture were available for this year and the hydrology approaches a “normal” year. The proceedings of each module are described in the next chapters.

HYDROLOGICAL MODULE

The hydrological module is the Mike 11 model of CPP. The gates of the main regulator are set in such a way that the preferred target water level in the Lohajang River is maintained throughout the monsoon. The model generates the average monthly water levels for 21 locations in the CPP area. For the dry season the water levels are reduced/increased at the same rate as was observed during the dry season of 93/94, whereby for each target option the average water levels as obtained from the model served as a starting point.

For each target option a specific gate setting is needed to maintain the preferred target water level. For each option the specific gate setting is used to create a land type map according to the MPO specifications:

The generated water levels and the land type maps are used as input for the GIS module.

GIS MODULE

Within the GIS module the generated water levels for each option are used to calculate the monthly inundated areas for the F3, F2, F1 and F0 land types in a way that is described by de Graaf *et al*. (2000). The generated flooded area serves as an input for the Fisheries and the Agriculture modules.

FISHERIES MODULE

All options are compared with the situations of the season 93/94, which is considered as a pre-project baseline situation. The monthly CPUA for the different land types for this year are used to calculate the annual fish catch for the different water target level options and are presented in Table 1.

DATE	CPUA (kg/ha/month)		
	F3	F2	F1
May-93	1.83	0.53	0.10
Jun-93	3.47	3.11	0.62
Jul-93	3.03	2.35	0.47
Aug-93	15.02	3.20	0.64
Sep-93	84.01	15.49	3.09
Oct-93	64.52	20.16	4.03
Nov-93	46.51	29.70	5.94
Dec-93	25.39	8.08	1.61
Jan-94	20.64	2.24	0.44
Feb-94	42.68	3.14	0.62
Mar-94	6.41	0.00	0.00
Apr-94	4.80	0.00	0.00

Table 1: The monthly Catch Per Unit of Area used as input for the fisheries module.

For the distribution of the catch over the different types of fishermen -- Professional, Occasional and Subsistence -- the distribution as observed during 1993/94 is used:

Professional 25%
Occasional 42%
Subsistence 33 %

AGRICULTURE MODULE

Due to lowering of the water level in the Lohajang River, drainage will improve and the different land types will become dryer and even shift from one type to another; i.e. some of the F3 land will become F2, some of the F2 becomes F1 and some of the F1 becomes F0. During the monsoon each land type has its own cropping pattern or land use suitability. For the comparison of agriculture under the different target water level, only the monsoon crop, i.e. Aman, was used, as any water management scenario does not affect the dry season crop during the monsoon.

Cropping patterns, production and financial outputs for the different land types during the monsoon are presented in Table 2.

General classification	Land type	Cropping pattern	Hired labour requirements (days/ha/crop)	Financial output (Tk/year)
High or Tan Jomi	F0-dry	T. Aman HYV	168	20559
Medium or Pachot Jomi	F1-dry	T. Aman local	172	11955
Medium or Pachot Jomi	F2-dry	DW Aman transplanted	113	8484
Low or Dopa Jomi	F3-dry	DW Aman Broad casted	134	9712

Table 2: Cropping pattern, production and financial outputs of agriculture on the different land types during the monsoon.

A suitable land type for DW Aman broadcasted the generated areas for F3-dry is used because DW Aman is grown only at the edges of the Beel or the higher F3 land. This is also the case for the other crops where the F2-dry, F1-dry and F0-dry are used.

In the agriculture module the dry areas as estimated per land type for the month of September in the GIS module are considered to be the total area under agriculture. For each land type this area is multiplied with the production rate or financial output of the specific crop growing at that land type.

ECONOMIC MODULE

In the economic module, the annual production of fish and rice[1] is translated into financial output. The financial output for agriculture was provided by the agriculture section of CPP and is presented in Table 2.
Details on the financial outputs used for fisheries are presented in Table 3, Table 4 and Table 5 and are based on CPP data.

[1] Rice crop for the monsoon only

OPERATIONAL COSTS PER UNIT OF GEAR	Cast	Seine	Liftnet	Scoops	Gill net	Traps	Lining
Investments Gear (Tk)	1500	30000	150	50	200	3000	200
Duration (years)	4	3	1	1	2	2	1
Investment others (Tk)		15000					
Duration others (Years)		6					
Investment per year (Tk)	375	4167	150	50	133	1500	200
Fishing Time (hours)	3	2.41	2.48	2.21	2	2	2.5
Annual fishing hours	93	8	84	196	58	26	26
Annual fishing days	9	1	8	20	6	3	3
GROSS PRODUCTION F3 WATER							
% of Production	22%	9%	10%	28%	15%	10%	6%
Annual yield per ha (181 kg/ha/yr.)	40	16	18	51	27	18	11
CPUE average kg/fishermen/day	1.29	5.16	0.54	0.57	0.94	1.37	1.03
No fishermen/ha/year to catch the total	31	3	34	89	29	13	11
Relative fishing effort	0.19	0.07	0.31	0.42	0.11	0.33	0.16
INPUTS							
Investments per ha/year	71	292	47	21	14	491	32
Real Labour days * 50 TK	463	38	419	982	289	132	132
Fish price Tk/kg	70						
OUTPUTS FINANCIAL							
Gross Product Value per gear per ha (Tk)	2787	1140	1267	3548	1901	1267	760
Total Inputs per gear per ha financial (Tk)	71	292	47	21	14	491	32
Net Profit per gear per ha (Tk)	2716	849	1221	3527	1886	777	728
Total profit/ha Financial (Tk)	11703						
Profit/kg (Tk)	65						

Table 3: Details of financial analysis of fisheries at F3 land type

OPERATIONAL COSTS PER UNIT OF GEAR	Cast	Seine	Liftnet	Scoop	Gill net	Traps	Lining
Investments Gear (Tk)	1500	33000	150	50	200	3000	200
Duration (year)	4	3	1	1	2	2	1
Investment others (Tk)		15000					
Duration others (year)		6					
Investment per year (Tk)	375	4500	150	50	133	1500	200
Fishing Time (hours)	3.19	2	0.9	2.04	2	2	2.5
Annual fishing hours	49	3	11	105	32	10	14
Annual fishing days	5	0	1	11	3	1	1
GROSS PRODUCTION F2 WATER							
% of Production	22%	9%	10%	28%	15%	10%	6%
Annual yield per ha (82 kg/ha/yr.)	18	7	8	23	12	8	5
CPUE average kg/fishermen/day	1.18	5.65	0.69	0.45	0.77	1.70	0.89
No fishermen/ha/year to catch the total	15	1	12	51	16	5	6
Relative fishing effort	0.08	0.03	0.34	0.39	0.18	0.16	0.05
INPUTS							
Investments Tk/ha/year	29	153	51	19	25	239	10
Real Labour days * 50 TK	244	13	53	525	160	48	69
Fish price Tk/kg	70						
OUTPUTS FINANCIAL							
Gross Product Value per gear per ha (Tk)	1263	517	574	1607	861	574	344
Total Inputs per gear per ha financial (Tk)	29	153	51	19	25	239	10
Net Profit per gear per ha (Tk)	1234	364	523	1588	836	336	335
Total profit/ha Financial Tk)	5215						
Profit Tk/kg	64						

Table 4: Details of financial analysis of fisheries at F2 land type.

OPERATIONAL COSTS PER UNIT OF GEAR	Cast	Seine	Liftnet	Scoop	Gill net	Traps	Lining
Investments Gear (Tk)	1500	33000	150	50	200	3000	200
Duration (year)	4	3	1	1	2	2	1
Investment others (Tk)		15000					
Duration others (year)		6					
Investment per year (Tk)	375	4500	150	50	133	1500	200
Fishing Time (hours)	3.19	2	0.9	2.04	2	2	2.5
Annual fishing hours	6	0	1	13	4	1	2
Annual fishing days	0.59	0.03	0.13	1.28	0.39	0.12	0.17
GROSS PRODUCTION F1 WATER							
% of Production	22%	9%	10%	28%	15%	10%	6%
Annual yield per ha (82 kg/ha/yr.)	2	1	1	3	2	1	1
CPUE average kg/fishermen/day	1.18	5.65	0.69	0.45	0.77	1.70	0.89
No fishermen/ha/year to catch the total	2	0	1	6	2	1	1
Relative fishing effort	0.01	0.00	0.03	0.04	0.02	0.02	0.01
INPUTS							
Investments Tk/ha/year	3	14	5	2	2	24	1
Real Labour days * 50 TK	30	2	7	64	19	6	8
Fish price Tk/kg	70						
OUTPUTS FINANCIAL							
Gross Product Value per gear per ha (Tk)	154	63	70	196	105	70	42
Total Inputs per gear per ha financial (Tk)	3	14	5	2	2	24	1
Net Profit per gear per ha (Tk)	151	50	65	194	103	46	41
Total profit/ha Financial (Tk)	649						
Profit Tk/kg	65						

Table 5: Details of financial analysis of fisheries at F1 land type

SOCIO ECONOMIC MODULE

The socio-economic module takes into account how the benefits and losses of the different options are distributed over the different social strata in the rural area of CPP. It considers the following social strata:

Landless

Marginal farmers

Small farmers

Medium farmers

Large farmers

The combined results of the Household survey and the Agriculture Monitoring Plot survey allowed researchers to estimate the land ownership of the Net Cropped Area and the Beels[2] in the CPP area, which is presented in Table 6.

Farmer	No HH	% of Rural HH	% of NCA	Area (ha)
Landless	19890	69%	0%	0
Marginal	2509	9%	11%	1080
Small	4589	16%	44%	4341
Medium	1362	5%	26%	2539
Large	475	2%	20%	1991
Total	28825	100%	100%	9952

Table 6: Distributions of the Net Cropped Area (fishing area included) over the rural population in the CPP project area.

In Table 7 the distribution of the catch over the rural population in CPP is presented. The data are a combination of the Household survey of CPP (1992) and the FAP 17 data for the North Central Region, and it was assumed that all professional fishermen belong to the "landless" category.

[2] Beels should be included as the model works with shifting land types i.e. F3-wet (beel) shifts to F3 dry (DW aman)

HH type	Occasional	Subsistence	Professional
Large farmers	0%	0%	0%
Medium farmers	2%	3%	0%
Small farmers	12%	21%	0%
Landless & Marginal farmers	86%	76%	100%
Total	100%	100%	100%

Table 7: Distribution of the catch over the rural population in the CPP project area.

The data in the two tables allows us to parcel the agriculture benefits and the fisheries losses for the different target water level options over the different categories of the rural population in the CPP area. Within the analysis the professional fishermen and their catch and the rest of the rural population with its subsistence and occasional catch are treated separately.

In this module the following assumptions are used:

The distribution of the NCA over the social strata is the same[3] for the different land types (F3,F2, F1, and F0). Exclusively the landless and marginal farmers carry out the hired labour needed for the different crops.

All calculations are on a Household basis with 5.5 persons in a household..
Annual income: large farmer, 80 000 Tk; medium farmer, 53000 Tk; small farmer, 31000 Tk; marginal farmer, 19 000 Tk; landless 15000 Tk
Fish price 70 Tk/kg, Labour 50 Tk/day, 1 US$ = 50 Tk

The availability of protein for consumption is calculated with the ***subsistence catch only***. For the transformation of “Wet fish weight” to “Dry protein” a conversion factor of 0.174 is used and the daily requirement of protein was set at 43 g/capita/day.

[3] In reality this is not the case; medium and large farmers possess more F1 and F0 land (CPP Household survey, 1992).

RESULTS

SHIFT IN WATER AND LAND

Due to the lowering of the water level in the Lohajang River, drainage is improved and the extent of flooding will be less -- i.e. the area becomes drier. In Figure 3 and Figure 4 for the two extreme options, without CPP and a 10.50 m + PWD target level, the inundated and dry area per land type throughout the year is presented and its is clear that especially the area of dry-F0 increases substantially with a reduction of the flooded areas of F2 and F1.

Figure 3: Monthly flooded and dry areas for the different land types without CPP

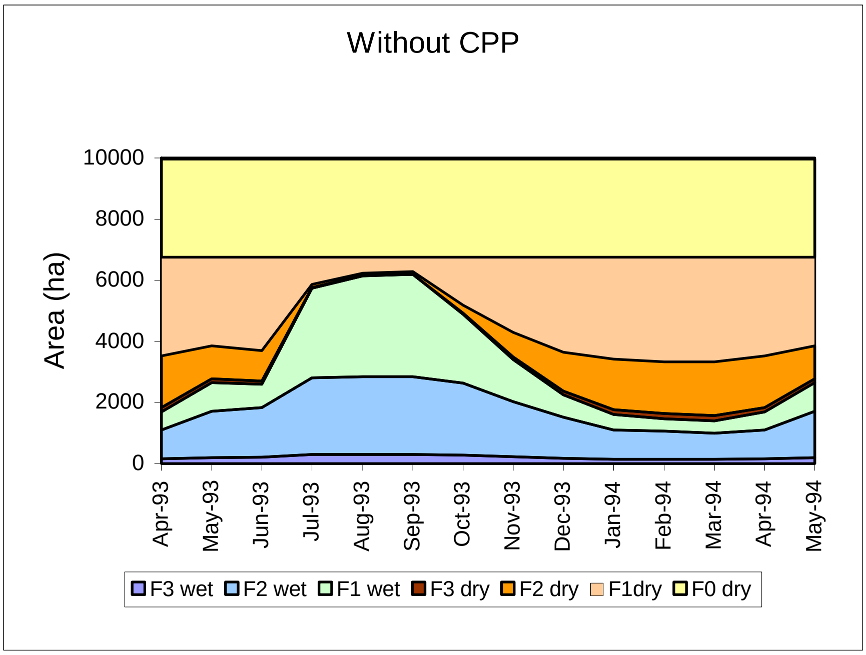
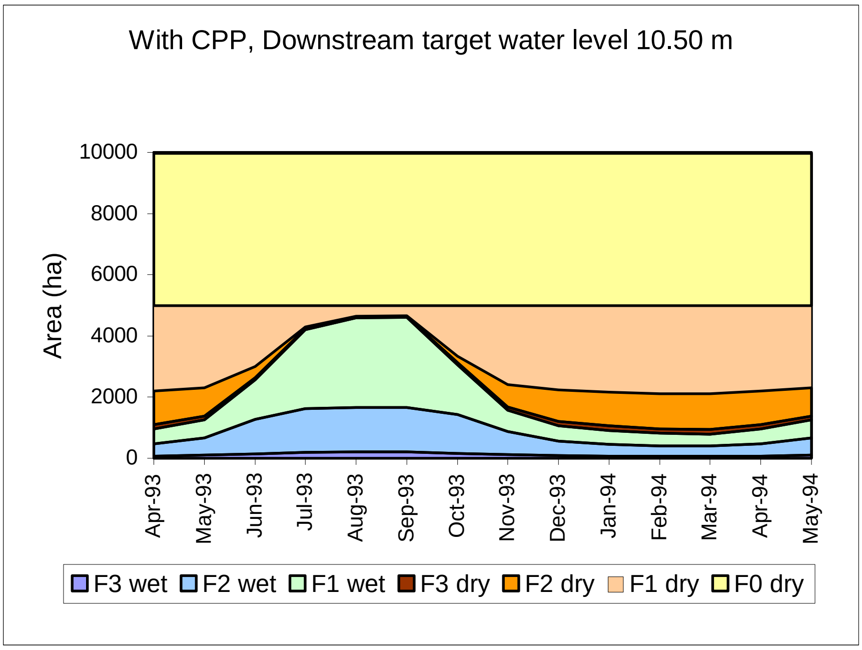


Figure 4: Monthly flooded and dry areas for the different land types with a level of 10.50 m + PWD in the Lohajang river.

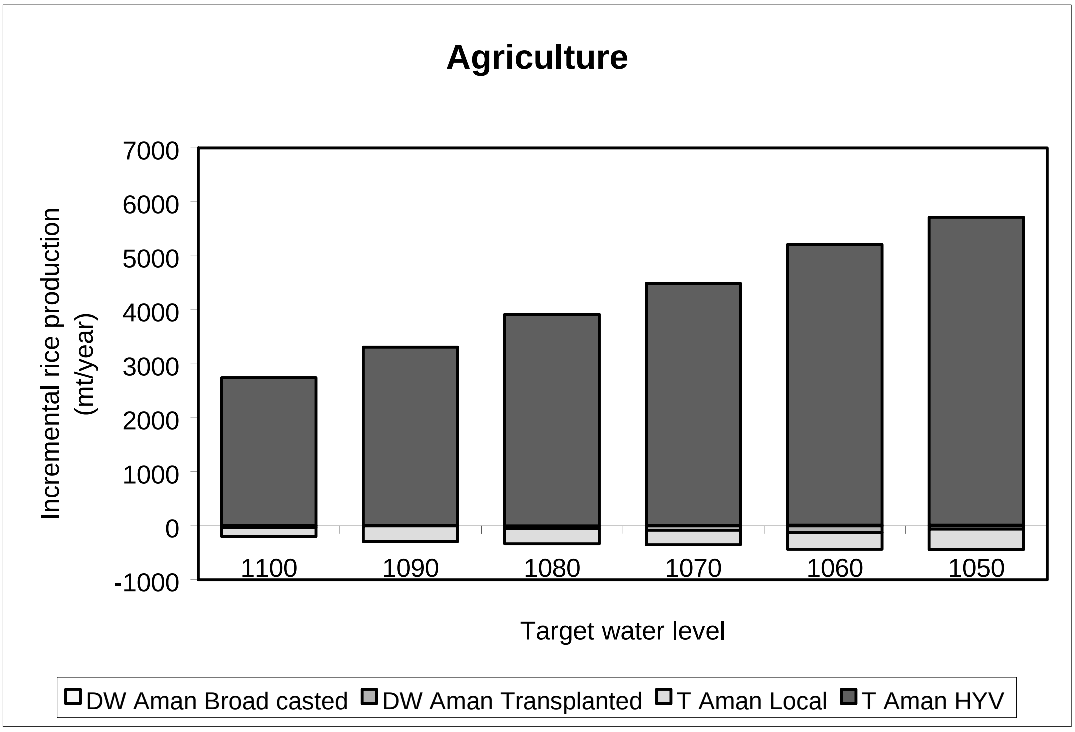


Production and Value

The reduction of dry F2 and F1 area and the increase in dry F0 area is also reflected in the rice production. By lowering the water level of the Lohajang River, the production of DW transplanted Aman and T Aman locally will decrease, while the production of DW Aman broadcasted will increase slightly. The benefits are found in the large incremental production of T Aman HYV (Figure 5). The total rice production[4] will increase by 5 300 mt/year, from 11 7000 mt/year for the pre-project phase to 17 100 for the 10.50 meter water level.

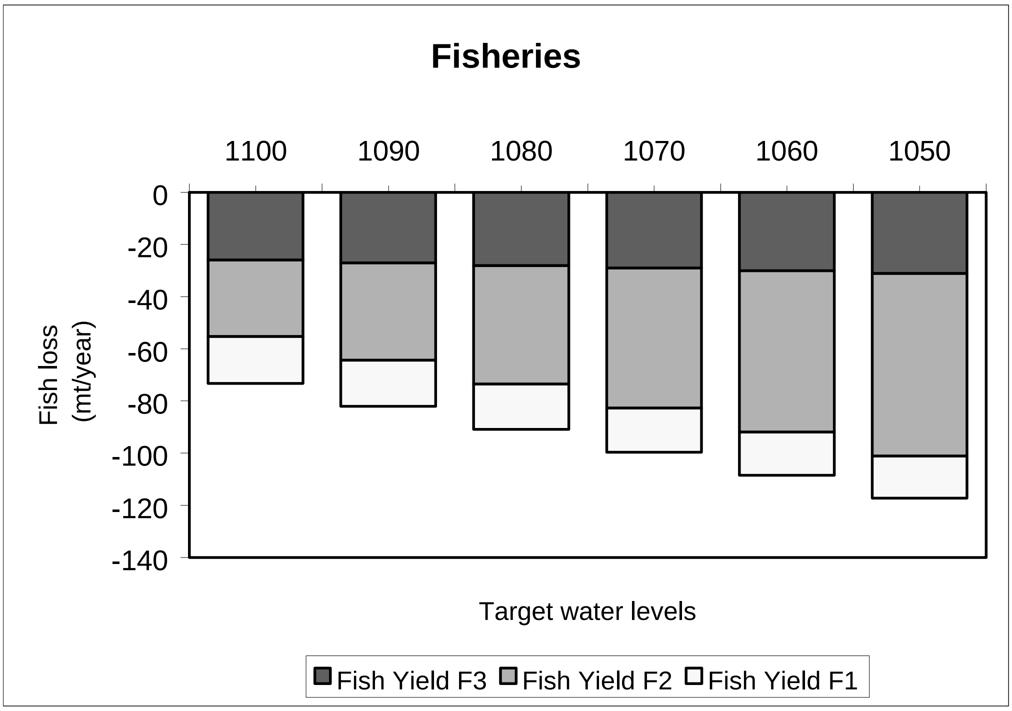
[4] During the kharif/monsoon season

Figure 5: Incremental rice production at different target water levels of the Lohajang river.



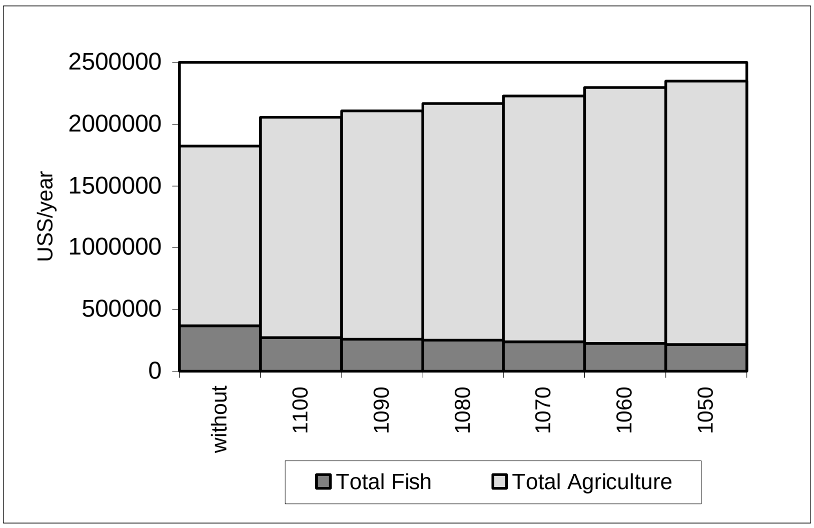
The consequence of a drier CPP area there will be reduction of the fish catch, especially from the F2 and F1 areas (Figure 6). The total fish catch will be reduced by 41%, from 285 mt/year for the pre-project situation to 168 mt/year for the 10.50 m target level.

Figure 6: Reduced fish catch in the CPP project area for the different water target levels



On financial terms the benefits obtained from agriculture outweighs the losses from fisheries and the value added increases with 0.5 million US/year from 1.8 million US/year for the without CPP situation to 2.3 million US/year for the 10.50 meter Target water level (Figure 7).

Figure 7: The total "value added" for agriculture and fisheries as estimated by the model for the different water management options of CPP.



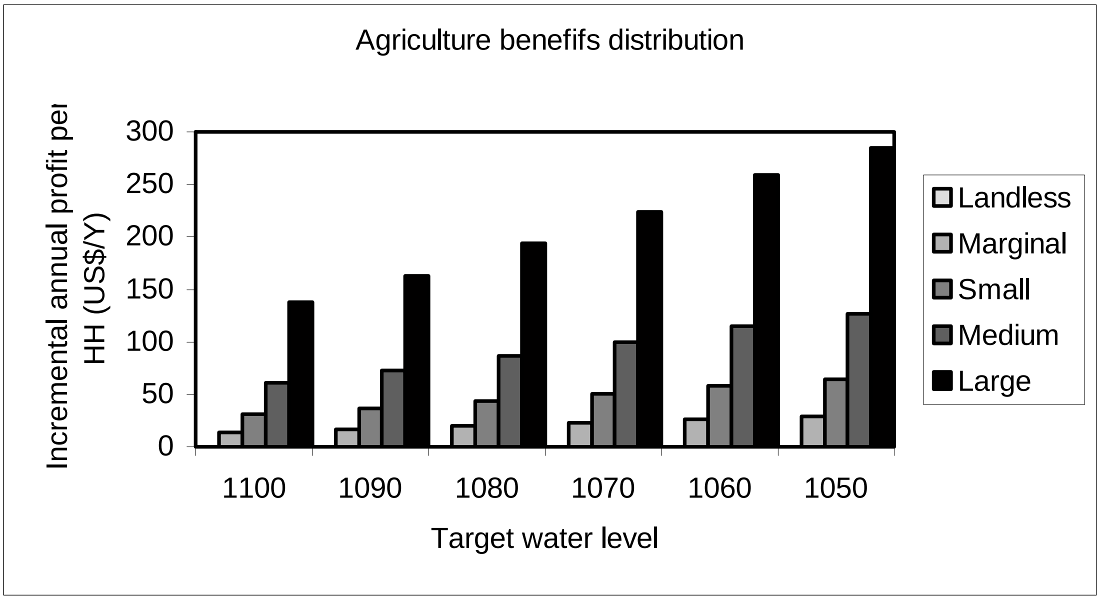
SOCIO-ECONOMIC ASPECTS

Increased financial outputs are not the only justification of an intervention; it is the overall policy and the outputs of an intervention in relation to this overall policy that justifies or rejects an intervention. If the overall policy is to increase rice production, then the results of the estimates would justify the implementation of the 10.50-meter Target level. However, if the overall policy includes poverty alleviation, it is essential to consider how much the rural poor are gaining from the intervention. This is done by looking at the distribution of the benefits/losses over the different social strata. The model looks at professional and subsistence fishing combined with occasional fishing separately.

Agriculture

The large farmers, because they own more land, get the highest incremental profit from the agricultural improvements, ranging from $140–285 US/household/year, for respectively the 11.00-meter and the 10.50-meter scenario. The marginal farmers, in comparison, receive incremental profits ranging from $14-29 US/household/year, and the landless who have no direct incremental profit at all (Figure 8). In relation to the annual income also the large farmers will have the highest contribution as their income increases with 9-18%, this in comparison with the rate for marginal farmers which is in the range of 4-8% (Table 8)

Figure 8: Distribution of the direct incremental benefits of agriculture for the different water target levels over the different social strata in CPP.



Type	Water target levels					
	1100	1090	1080	1070	1060	1050
Landless	0%	0%	0%	0%	0%	0%
Marginal	4%	4%	5%	6%	7%	8%
Small	5%	6%	7%	8%	9%	10%
Medium	6%	7%	8%	9%	11%	12%
Large	9%	10%	12%	14%	16%	18%

Table 8: Distribution of the incremental agriculture benefits for the different target water levels in percentage of the average annual income of the different social strata in CPP.

Fisheries

If the total annual catch of Occasional and Subsistence catch in CPP is analysed in relation to the total number of rural households and their annual income from all economic activities (Table 9), we come to the same conclusions as FAP 17 (1995). Fishing is an economic activity, but the significance of fishing within the annual income should not be overstressed. It is one of many sources, which becomes relatively more important during the flood season when all three of their main sources (agriculture labour, non-agriculture labour and self-employment) are at their annual low (FAP 17, 1995).

HH type	No HH	Annual catch	Value annual catch	Value catch as % of annual income	% of required daily animal protein intake[5]	Fishing days	Labour day equivalents
Large farmer	475	0.0	0	0.00%	0.00%	0	0
Medium farmer	1 362	4.3	300	0.57%	0.55%	7	6
Small farmer	4 589	8.7	608	1.96%	1.20%	13	12
Land less & Marginal farmers	22 399	8.3	580	3.05%	0.88%	13	12

Table 9: Key parameters of the catch of non-professional fishermen in the CPP project area in relation to their land holdings (source CPP 2000).

Reduction in the floodplain area will cause losses in fisheries, and for fisheries the picture is the inverse of agriculture: the large farmers have no losses as they do not fish, and the losses are mainly felt by the marginal farmers and landless, where 50-80 mt/year is lost (Figure 9). Due to the large number of landless and marginal farmers (23 000 HH) on an individual household basis the loss becomes only $3-6 US/household/year (Figure 10) In terms of income this is equivalent to 1-1.5% of their annual income per year (Table 10).

[5] Calculated with subsistence catch only

Figure 9: Distribution of total annual fisheries losses over the different social strata of the rural population of CPP.

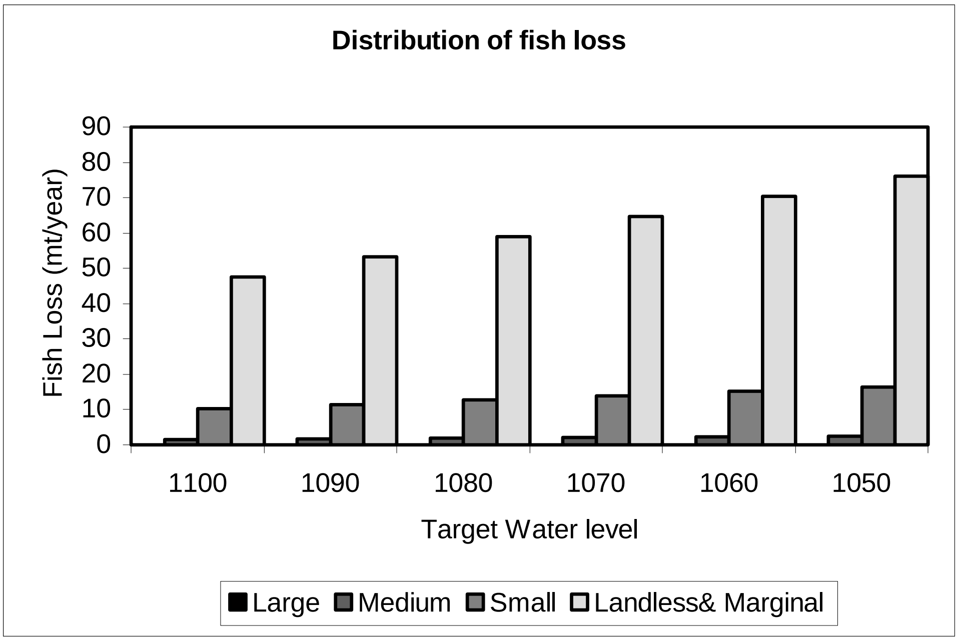
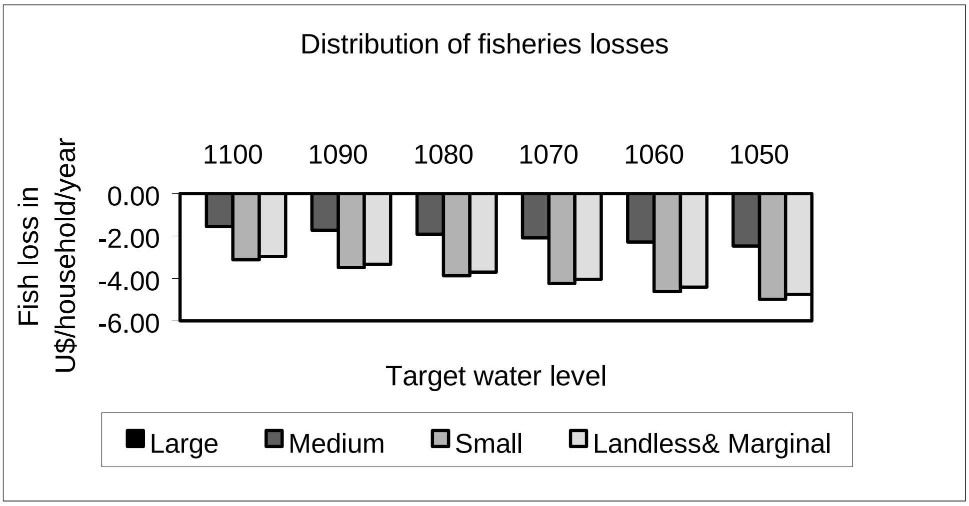


Figure 10: Distribution of the fish losses for the different water target levels over the different social strata in CPP.



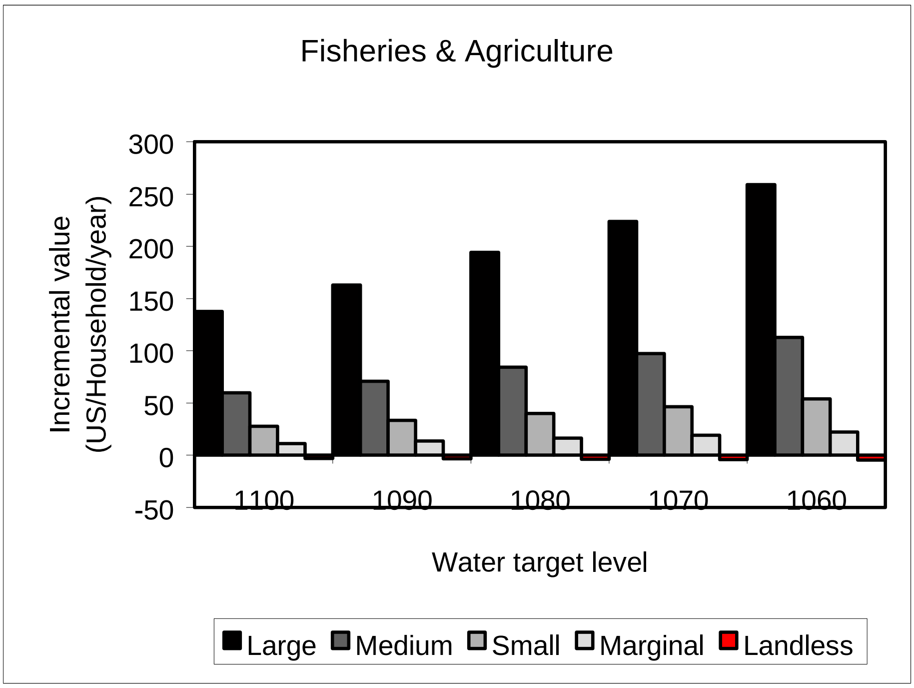
HH type	Water target level					
	1100	1090	1080	1070	1060	1050
Large	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Medium	-0.15%	-0.16%	-0.18%	-0.20%	-0.22%	-0.23%
Small	-0.50%	-0.56%	-0.62%	-0.68%	-0.74%	-0.80%
Landless & Marginal	-0.88%	-0.98%	-1.09%	-1.19%	-1.30%	-1.40%

Table 10: Distribution of the fish losses for the different target water levels in percentage of the average annual income of the different social strata in CPP.

THE COMBINED IMPACT ON AGRICULTURE AND FISHERIES

Combining the agricultural benefits and the fisheries losses indicates that all households except the landless will have a direct net profit (Figure 11). The landless, however, will lose $3-6 US/Household/year. Considering the fact that they form the majority of the rural households (68%) and they are the poorest and most vulnerable group, this cannot be neglected.

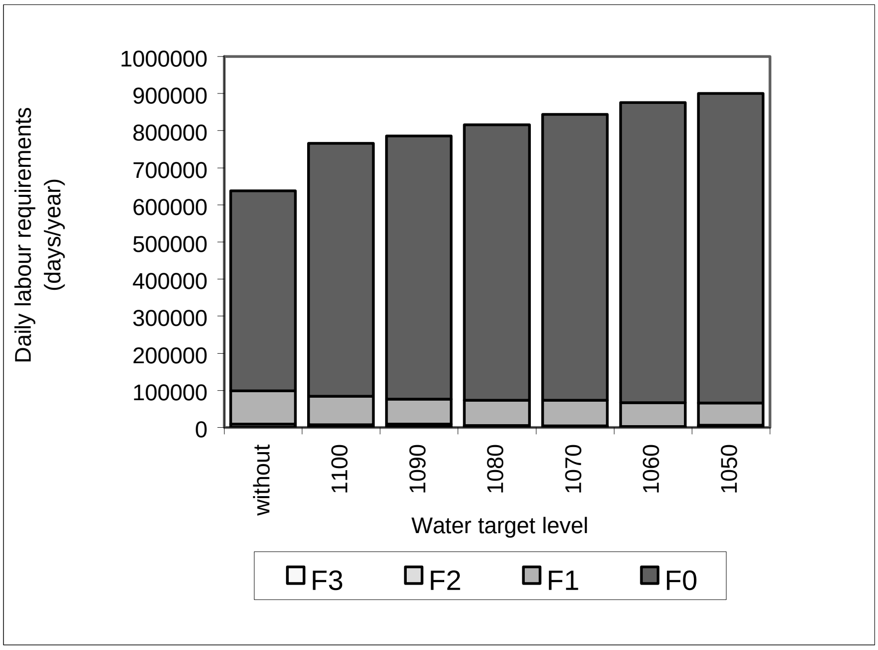
Figure 11: The distribution of the total profits of the different scenarios over the social strata of the rural population in the CPP area.



INCOME GENERATION AS A SPIN-OFF OF AGRICULTURE DEVELOPMENTS

It is often stated that developments in agriculture will generate income-generating activities for the landless and marginal farmers through daily labour. Estimates on the actual daily labour requirements for the different crops are obtained from the Agriculture Monitoring Plots of CPP and were presented in Table 2. The differences in requirements seem to be small, but they become substantial if they are estimated for the whole of the CPP project area for the different scenarios (Figure 12).

Figure 12: Daily labour requirements for agriculture in the CPP area as estimated for the different water target levels.



Indeed it can be expected that on the long run the daily labour requirements will increase with 280 000 days/year with the 10.50 meter scenario (Table 11)

Target level	Total Incremental days	Days/HH/year	Tk/HH/Year
1100	127597	6	285
1090	148367	7	331
1080	177876	8	397
1070	206386	9	461
1060	237775	11	531
1050	262662	12	586

Table 11: Incremental daily labour requirements for the different target water levels and its income generation for landless and marginal farmers in the CPP area.

This would mean that 6-12 labour days per year would be generated for the landless and marginal farmers if they provide daily labour exclusively[6], and the overall impact of the different scenarios on the different groups in the rural area is presented in Table 12.

HH type	Target water level					
	1100	1090	1080	1070	1060	1050
Large	138	163	194	224	259	285
Medium	60	71	84	97	113	124
Small	28	33	40	46	54	59
Marginal	17	20	24	28	33	36
Landless	3	3	4	5	6	7

Table 12: Incremental annual income per household (US$/year) for the different social strata as estimated with the fisheries-agriculture model for the different target water levels

From the exercise it could be concluded that the small, medium and large farmers will profit from the interventions and they will be better off. The marginal farmers and landless will have a slight benefit or will not lose from the interventions.

[6] It can be expected that the urban poor are also involved

DAILY ANIMAL PROTEIN INTAKE

FAP 16 (1995) studied the fish consumption of the rural household in the CPP area and concluded that open-water fisheries are a major source of animal protein consumption of the rural poor in the CPP area. The results were based on a household consumption survey in a small number of villages in the CPP area. From all four areas studied the Tangail CPP area had the lowest average daily consumption of 11 grams of fish/capita/day, equivalent to 1.9 gram of fish protein per capita/day. The fish consumed is both caught and bought.

Unfortunately in 1992 the results could not be compared with the catch statistics of CPP as they were not available. Reliable catch statistics for CPP are now available and the role of subsistence fisheries in respect to animal protein consumption of the rural population can be analysed and has been incorporated in the model. The results are presented in Table 13 and Table 14.

HH type	Water management scenario						
	Without	1100	1090	1080	1070	1060	1050
Large	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Medium	1.4	1.0	1.0	0.9	0.9	0.8	0.8
Small	3.0	2.2	2.1	2.0	1.9	1.8	1.7
Landless & Marginal	2.2	1.6	1.5	1.5	1.4	1.3	1.3

Table 13: Estimated daily per capita available fish for consumption from subsistence fishing for the different water management scenarios in CPP.

The present availability of fish from subsistence fishing for daily consumption is low and is in contrast with the general belief in Bangladesh that subsistence fishing is an important source of protein; but on the other hand, they are consistent with the findings of FAP 16 indicating that the average daily fish consumption in the CPP area was 50% below the values as observed in the other studied areas (FAP 16, 1995).

HH type	Water management scenario						
	Without	1100	1090	1080	1070	1060	1050
Large	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Medium	0.55%	0.41%	0.39%	0.37%	0.36%	0.34%	0.32%
Small	1.20%	0.89%	0.85%	0.82%	0.78%	0.74%	0.71%
Landless & Marginal	0.88%	0.65%	0.62%	0.60%	0.57%	0.54%	0.52%

Table 14: Daily animal protein provided by subsistence fishing in percentage of the total required daily animal protein intake (43 g/capita/day).

At present about 0.88% of the daily required protein intake of the landless and marginal farmers could be provided through subsistence fishing of these households, and this would decrease to 0.52 % if CPP implements its 10.50 meter scenarios.
The results could be the reflection of the importance of income for the rural poor,. They will only fish if there is no other alternative, and they will buy the fish if they have money. This would mean that subsistence fisheries becomes less important in areas where alternative income is more easily available, and this phenomena could be checked with the data on subsistence fishing and fish consumption of the Helen Keller Foundation in Bangladesh.

Professional fishermen

Key parameters of the catch and income of professional fishermen before CPP is presented in Table 15. With an annual income of about Tk 10000 per year, they can be grouped among the poorest of the inhabitants of CPP and changes in fisheries due to interventions of CPP will hit them harder then the other poor, as their income is mainly provided through fishing.

Key parameters	
No of fishermen	355
Annual catch (mt/year)	54
Annual catch per HH (kg/HH/year)	153
Annual income (Tk/HH/year)	9931

Table 15: Key parameters of professional fishermen in the CPP area before the interventions of CPP.

The estimated impact of the different target water levels on the income of the professional fishermen is presented in Table 16. It can be concluded that the professional fishermen will always be impacted by CPP interventions, which is normal as CPP becomes drier due to the interventions. The extent depends on the extent of the conversion of flooded area into agricultural land, and losses range from 26% to 41% of annual income for respectively the 11.00 and the 10.50 meter scenario.

Parameter	Water management scenario						
	Without	1100	1090	1080	1070	1060	1050
Annual catch	54	40	39	37	35	34	32
Kg/HH/YEAR	153	114	109	104	99	95	90
Annual income	9931	7380	7075	6769	6464	6158	5853
Loss in income		26%	29%	32%	35%	38%	41%

Table 16: Estimated loss of income of professional fisheries for the different water management scenarios of CPP.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE DEVELOPMENTS

The model can predict future trends in developments based on shifting of land types under a more or less steady state condition, i.e. no large changes in population structure, income generation activity, or what is more important fishing effort. In principle, any scenario can be predicted as long as the hydrological model can estimate shifting patterns in dry and flooded area.

The model could be further improved by adding:

- population growth rate;
- more details on cropping patterns and inputs, i.e. the use of fertilisers or pesticides per crop could be added to have an idea of pesticide loads, etc.;
- the bio diversity index
- Investment, Operation and Maintenance costs

Fine-tuning of the model towards real developments in fisheries can only be done if it is linked with the output of *“adapted dynamic fish stock assessment models"* where fishing effort and water management or its impact on the extent of flooding is related to fish production, species-wide, in a three-dimensional way.

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