

THEMATIC REPORT

Geographic Information Systems (GIS) and inland fishery management

Stratified inland fisheries monitoring using GIS

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Introduction

Inland capture fisheries provide a valuable contribution to food security for the lower strata of society in many parts of the developing world. However, accurate information on the sector is often difficult to obtain. Traditionally, yields are being calculated as being the product of the Catch Per Unit of Effort and the effort ($Y = CPUE * f$).

In marine fisheries this is a valid method as both the catch (Y) and effort(f) are relatively easy to establish (effort can be defined as for instance tonnage [marine], horsepower [marine], or number of nets [inland], number of fishers [inland], etc). The bulk of marine catches is taken by large commercial vessels, fish are landed on a centralized landing site, and most of the produce is being exported. All of these factors make it easier to record the catch and effort data involved.

For many inland fisheries this is not the case. The bulk of the catch is taken by dispersed small-scale fishermen, the fishing activities are of an informal nature, and fishers are operating in remote rural areas. Part-time fishing is the norm, especially mixed farming/fishing lifestyles on floodplains. Most inland fisheries produce is consumed domestically and much of it within the communities where the fishing occurs (Coates, 2002).

Taking these obstacles in collecting reliable data into account, one option to consider when investigating inland fisheries is to use Geographical Information Systems (GIS). A GIS is defined as an integrated assembly of computer hardware, software, geographic data and personnel designed to acquire, store, manipulate, analyze, display and report all forms of geographically referenced information. Simply put, a GIS combines layers of information about a place giving a better understanding of that place (Figure 1).

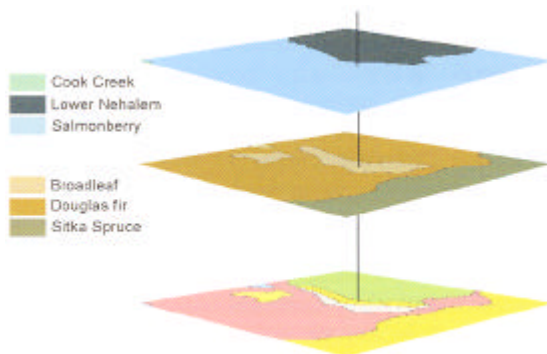


Figure 1, The concept of information layers (Mitchell,

An example of GIS use in inland fisheries monitoring is the floodplain fisheries monitoring programme, as developed in the Compartmentalization Pilot Project in Bangladesh (de Graaf *et al*, 2001, de Graaf, in press a/b).

Floodplain fisheries monitoring in the Compartmentalization Pilot Project (CPP), Tangail area, Bangladesh.

The CPP was a water management project implementing a controlled flooding concept in its project area. To be able to assess the impact on fisheries of the water-management measures that were taken, a fisheries monitoring programme was set up. Facing the above mentioned problems concerning the collection of reliable inland fisheries data, a habitat-stratified floodplain fisheries monitoring programme was developed. This programme was based on traditional catch and effort data recording, collecting these data from standard habitat types, and extrapolating them over the whole project area using hydrological modelling and GIS techniques.

Basic principles of habitat stratified floodplain fisheries monitoring

The principle of the fisheries monitoring programme used by CPP is a habitat stratification of catch and effort monitoring. Stratification means that the monitored area is divided into different habitat-types. Of each habitat-type a small representative part with a known inundated area is selected. These standard sites then are monitored closely with a traditional catch and effort monitoring programme (determining the CPUE, *f*, and Yield). In this case the traditional methods are applicable, because of the limited size of the sampling sites. After the Yield per standard site is established the Catch Per Unit of Area (CPUA) can be calculated by dividing the Yield of the standard site by the inundated Area of the standard site.

Habitat classification

For the floodplain fisheries monitoring programme in the CPP area the land type classification of the Master Planning Organization (MPO) of Bangladesh was used. This MPO classification is well known by large groups of planners, scientists, departments, and farmers in Bangladesh. After careful consideration it was concluded that this system could be used for the fisheries monitoring programme in the CPP project. The MPO classification classifies land according to the risk of flooding for three consecutive days with a certain maximum water level. This risk of flooding determines which type of crops can be grown during the monsoon season. The different classes with their criteria are in Table 1.

Table 1, Land classification according to the Master Planning Organization

| Land classification | Risk of flooding | Maximum flooding depth for three days (cm) | Land use during the monsoon |
|---------------------|---------------------------|--------------------------------------------|-----------------------------|
| F ₀ | Very low risk of flooding | 0-30 | Sugarcane, vegetables, rice |
| F ₁ | Low risk of flooding | 30-90 | Rice |
| F ₂ | High risk of flooding | 90-180 | Rice, floating rice, fish |
| F ₃ | Certainly flooded | > 180 | Floating rice, fish |

The land types in a certain area only change if the water management in that area is changed. The developers of the stratified floodplain fisheries monitoring programme assumed that catch data obtained from a land type site was representative for the total flooded area of this land type, irrespective of the actual water level measured at that site. For instance, if the catch in 10 ha of flooded F3 land was well monitored during a certain period, it was considered representative for the total area of flooded F3 land during this period. This assumption allowed concentrating on the fixed sites within the project area. As a result a sound analysis was possible, considering even the limited amount of resources. Figure 2 shows the sampling sites of the most important habitats in the CPP area, while Figure 3 shows the different land types in the CPP area.

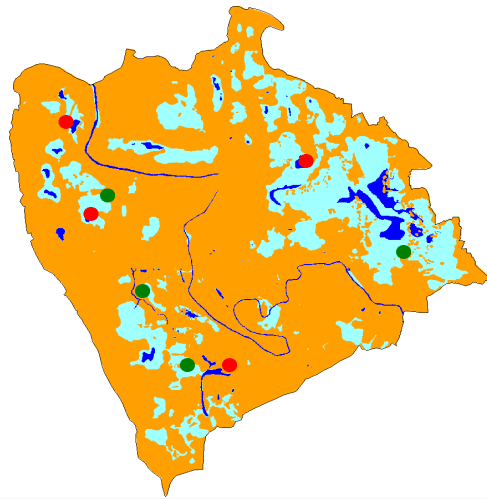


Figure 2, Sampling sites of the fisheries monitoring programme in the CPP project area (red F3 site, green F2 site)

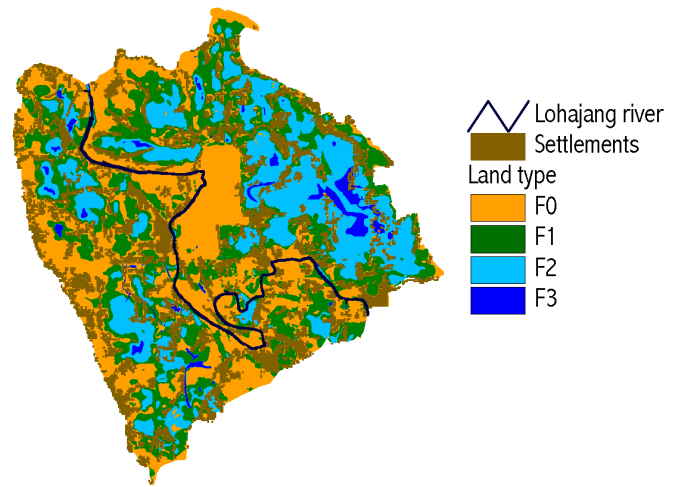


Figure 3, Landtypes in the CPP area

Determining the monthly Catch Per Unit of Area (CPUA)

Two surveys were done at the selected sites:

Catch assessment survey: providing information on the average monthly catch per fisher (CPUE) at a selected site. The daily catch of every individual fisherman at each site was monitored bi-weekly.

Frame survey: providing information on the average number of fishers (f) operating at a selected site. It consisted of regular standardised counting of the number of fishermen, and gears used.

From these two surveys the average monthly catch could be established per site ($CPUE * f = Catch$), after which the CPUA of the land type the site represented could be established ($[Catch_{Fx}] / [Area_{Fx}] = CPUA_{Fx}$). Table 2 and Table 3 show data collected in 1997, and the resulting calculated CPUA for the considered habitat type (F3 or F2). Table 4 gives the average yearly CPUA per habitat type.

Table 2, Fisheries data (1997) from F3 sampling sites

| Month | Number fishermen per day (f) | Catch per fishermen per day (Kg/day) (CPUE) | Daily Yield in sampled Area (Kg/day) (CPUE * f = Catch) | Monthly yield (kg/month) (Catch*days) | Sampled Area (Ha) | CPUA (Kg/ha/month) (Catch/Area) |
|-----------|------------------------------|---------------------------------------------|---------------------------------------------------------|---------------------------------------|-------------------|---------------------------------|
| January | 3 | 0.68 | 2.04 | 63.24 | 4.22 | 14.99 |
| February | 3 | 1.07 | 3.21 | 89.88 | 3.60 | 24.75 |
| March | 3 | 0.87 | 2.61 | 80.91 | 3.77 | 21.46 |
| April | 3 | 1.06 | 3.18 | 95.40 | 7.19 | 13.27 |
| May | 6 | 1.13 | 6.78 | 210.18 | 8.90 | 23.62 |
| June | 6 | 1.41 | 8.46 | 253.80 | 10.01 | 25.35 |
| July | 8 | 0.63 | 5.04 | 156.24 | 17.10 | 9.14 |
| August | 5 | 0.75 | 3.75 | 116.25 | 17.80 | 6.53 |
| September | 11 | 1.28 | 14.08 | 422.40 | 17.80 | 23.73 |
| October | 15 | 3.06 | 45.90 | 1422.90 | 12.23 | 116.35 |
| November | 8 | 0.96 | 7.68 | 230.40 | 6.52 | 35.34 |
| December | 4 | 0.91 | 3.64 | 112.84 | 5.63 | 20.04 |

Table 3, Fisheries data (1997) from F2 sampling sites

| Month | No fishermen per day (f) | Catch per fishermen per day (Kg/day) (CPUE) | Daily Yield in sampled Area (Kg/day) (CPUE * f = Catch) | Monthly Yield (Kg/month) (Catch *days) | Sampled Area (Ha) | CPUA (Kg/ha/month) (Catch/Area) |
|-----------|--------------------------|---------------------------------------------|---------------------------------------------------------|----------------------------------------|-------------------|---------------------------------|
| January | 9 | 0.74 | 6.66 | 206.46 | 11 | 18.77 |
| February | 0 | 0.00 | 0 | 0 | 11 | 0 |
| March | 0 | 0.00 | 0 | 0 | 11 | 0 |
| April | 0 | 0.00 | 0 | 0 | 11 | 0 |
| May | 0 | 0.00 | 0 | 0 | 11 | 0 |
| June | 0 | 0.00 | 0 | 0 | 11 | 0 |
| July | 5 | 0.56 | 3 | 86.80 | 11 | 7.89 |
| August | 15 | 0.72 | 11 | 334.80 | 11 | 30.44 |
| September | 13 | 1.25 | 16 | 487.50 | 11 | 44.32 |
| October | 9 | 2.57 | 23 | 717.03 | 11 | 65.18 |
| November | 15 | 0.85 | 13 | 382.50 | 11 | 34.77 |
| December | 3 | 1.50 | 5 | 139.50 | 11 | 12.68 |

Table 4, Average annual yields of the different habitats in CPP (kg/ha/yr or kg/km/year)

| | F ₃ (kg/ha/year) | F ₂ (kg/ha/year) | F ₁ (kg/ha/year) | River (kg/km/year) | Canals (kg/km/year) |
|----------------|--------------------------------|--------------------------------|--------------------------------|-----------------------|------------------------|
| 92/93 | 116 | 16 | 1 | 33 | 16 |
| 93/94 | 241 | 67 | 9 | 101 | 315 |
| 94/95 | 137 | 60 | 4 | n.a. | n.a. |
| 95/96 | 136 | 35 | 3 | n.a. | n.a. |
| 96/97 | 155 | 85 | 10 | 136 | 98 |
| 97/98 | 179 | 112 | 10 | 42 | 93 |
| 98/99 | 311 | 228 | 31 | 296 | 266 |
| Average | 182 | 86 | 10 | 87 | 112 |

Determination of flooded area of each habitat type

Gauges showing the water level were distributed over the whole CPP area. Water level measurements were recorded daily. The monthly average water level was calculated per gauge, after which the water level (the water table) over the whole project area was interpolated. See Figure 4

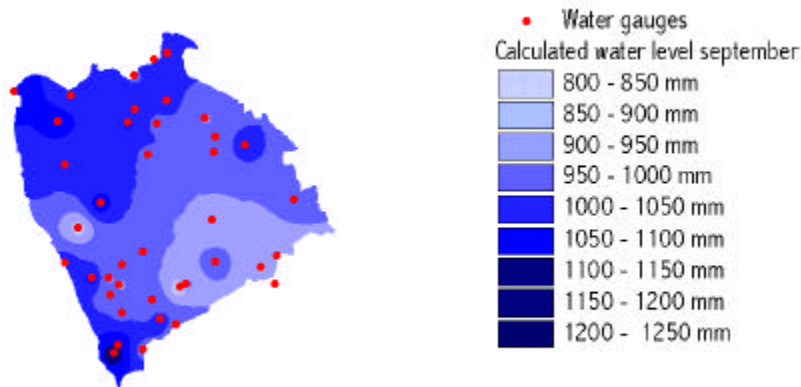


Figure 4, The interpolated water table of CPP

A Digital Elevation Model of the project area (Figure 5) was available, making it possible to do calculations in a GIS with the land levels (in the DEM) and the interpolated water-levels.

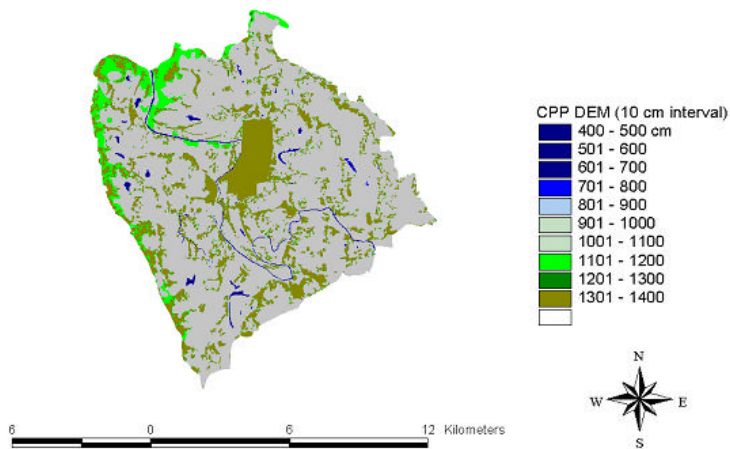


Figure 5, The Digital Elevation Model of the CPP area

This DEM was subtracted from the water levels, resulting in a flood map, showing inundated areas (Figure 6 and Figure 7)

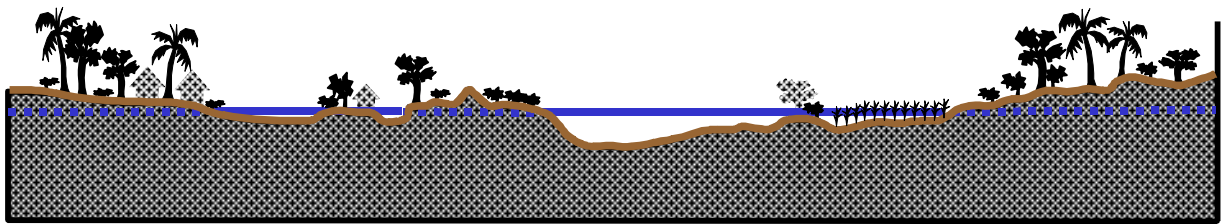


Figure 6, The subtraction of water level from land level (DEM)

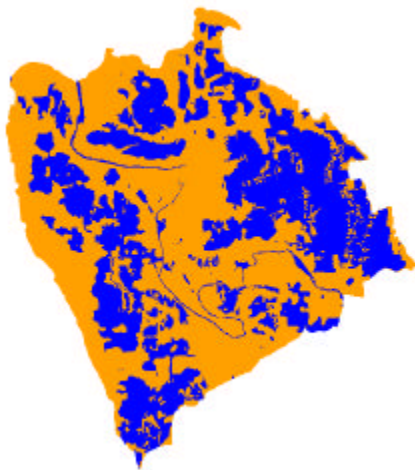


Figure 7, The resulting floodmap showing inundated areas in blue

This flood map was then used to determine the inundated area per land type, using the land-type map (Figure 8)

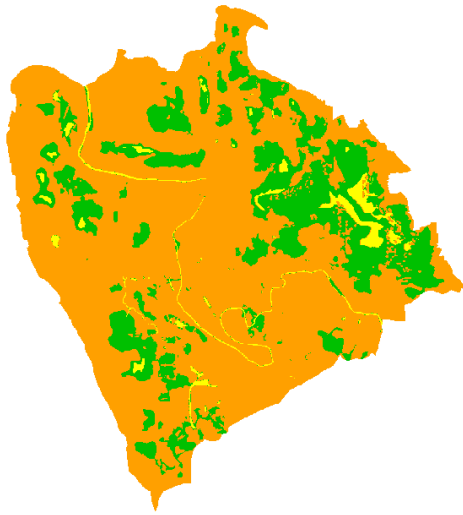


Figure 8, Inundated F3 land (yellow) and F2 land (green)

Determination of Yield

After this procedure it was possible to estimate the total catch of that month in the project area ($[CPUA_{F1} * Area_{F1}] + [CPUA_{F2} * Area_{F2}] + [CPUA_{F3} * Area_{F3}] + \text{etc} = \text{Total Catch}$). Table 5 shows the production per habitat type over the years that the monitoring programme was in place. These data do not show a significant negative influence of the project on capture fisheries production between the years that the project area was without watermanagement (1992 till 1995) and the years with watermanagement (1995 till 1999), taking into account that the flood season of 1992 was extremely dry, and the seasons 97 and 98 were very wet (long duration of flood, high flood levels).

Table 5, Catch per year (Mt) per habitat type in the CPP area

| | F3 | F2 | F1 | Lohajong river | Canals | Total |
|-------|----|-----|-----|----------------|--------|-------|
| 92/93 | 36 | 42 | 5 | 1 | 2 | 86 |
| 93/94 | 76 | 176 | 33 | 3 | 29 | 317 |
| 94/95 | 43 | 158 | 15 | n.a. | n.a. | 216 |
| 95/96 | 43 | 92 | 12 | n.a. | n.a. | 147 |
| 96/97 | 48 | 223 | 39 | 4 | 9 | 323 |
| 97/98 | 56 | 292 | 38 | 1 | 9 | 396 |
| 98/99 | 97 | 596 | 119 | 8 | 25 | 845 |

Conclusions and recommendations

The example of stratified floodplain fisheries in the CPP area has shown that GIS techniques provide an excellent tool in fisheries monitoring. Without this method it would be extremely difficult to have done this type of analysis. The applicability of the method in other areas depends on the availability of a Digital Elevation Model of the area, sufficient water level measurements (spread over the area, and frequently enough), and of course fisheries catch and effort data.

It is easily understood that the usefulness of GIS is not limited to floodplain monitoring only, but also extends to (but is not limited to) improving modelling capabilities, data management, data

quality control, and the improvement of communication between scientists, institutions, and policy makers. GIS is one tool allowing the integration of fishery and related data in a user-friendly manner.

However, many fishery biologists and policy makers involved in inland fisheries management (and statistics) are unaware of the technology and its potential for fisheries management. Therefore, an effort should be made to expose fishery biologists and policy makers to GIS techniques, and make them proficient into doing GIS-analyses on their data, and making them capable to communicate with GIS-experts their wishes concerning more complex analyses on their data.

A programme should be developed addressing these knowledge and capacity needs. This programme should deal with:

- Increasing the knowledge of GIS techniques among fishery biologists, for instance using the manual on the use of GIS in fisheries management and planning (de Graaf, *et al*, 2002)
- Building a global network of GIS-users in fishery biology, so that these can communicate their problems and newly developed techniques, and
- Investigate which limitations exist concerning the use of GIS (software, hardware, internet access, and data exchange limitations).

References

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