has a minor effect on the maximum size of the herds, it may well have implications for the viability of the remaining population after droughts. Secondly, the decrease of the flood may also have an impact on the frequency of droughts.

The above analysis shows again how sensitive the local economy in the Inner Niger Delta is to changes in the flooding regime. Although livestock is mobile and can one way or another mitigate damage from reduced water availability, livestock migration is unable to avoid significant losses during droughts. Despite statistical uncertainties, several conclusions can be drawn.

- The number of livestock increases with river height in the Inner Niger Delta. Nomadic pastoralists increase the size of their herds when water is available. This implies that the maximum sustainable population of livestock is limited by the availability of bourgou in the Inner Delta and thus by the flow of Niger and Bani Rivers into the Inner Delta.
- The maximum number of livestock will be negatively affected by the Fomi dam (Scenario 3). The most severe impact is expected on sheep and goats in Tombouctou, where the calculated decrease in average number of animals ranges between 10 to 15%. Negative impacts on cattle range between 2 to 4%.
- In the absence of Office du Niger and Sélingué, the number of cattle, sheep and goats in the regions of Mopti and Tombouctou are expected to increase on average with roughly 4 to 5% per year.

Fig. 7.7. Trends in cattle (top) and sheep and goats (bottom) populations in the Tombouctou region as calculated from estimated production functions and calculated impacts of the scenarios on the total area of bourgou.
Trucks filled with rice arrived in Sévaré and Mopti in August 2002 to fill the repositories with a new emergency food supply. Had a food shortage already been foreseen due to the low rains in the weeks before? Or was it already known in August that the forthcoming flood would be limited? With current technology, it is indeed possible to predict the inundation of the Inner Delta two or even three months beforehand. Weather satellites continuously register the clouds all over the world and these data are used to estimate daily rainfall. This information has been entered into early warning systems to forecast food shortage in semi-arid areas (Global Information and Early Warning System, www.fao.org/giews). So, the food aid agencies may have been informed that the rainfall in the catchment area of the Upper Niger was limited in August 2002 and hence the peak river flow would be reduced in September and also the maximal flooding of the Inner Delta in October-November. FAO-experts in Rome may know earlier than the farmers in the Inner Delta that a food shortage is to be expected.

This Chapter will show the effect of flooding on the annual rice production. If this effect can be demonstrated, it allows quantification of the impact on rice production in the Inner Delta resulting from the water usage by Sélingué and the Office de Niger irrigation zone. To do this, it is necessary to separate the effect of local rain on the rice production from the effect of flooding itself. As shown in Chapter 2.1, flooding and local rainfall in the Inner Delta coincide. That is why we will investigate the relationship between rice production and flooding separately for years with different levels of local rainfall.

This Chapter is organised as follows. Chapter 8.2 will show the dependence of the rural economy in Mali on rainfall. Chapter 8.3 will give some background information on cultivating rice in the floodplain area. Chapter 8.4 will deal with rice production in the floodplains and will show that in the Inner Delta the effect of rainfall is limited but that flooding has a significant impact on the rice production. Chapter 8.5 will conclude that the Sélingué reservoir and the irrigation by Office de Niger have a substantial effect on the rice production in the Inner Delta and that the envisaged Fomi dam would have a very large impact.
8.2 Annual cereal production and rainfall

As in other Sahel countries, the rural production of Mali varies from year to year depending on the fluctuating rainfall. The Cellule de Planification et de Statistique (CPS), a service within the Ministère du Développement Rural (MDR), published in 2001 a document summarizing many rural statistics (CPS-MDR 2001). The data were extracted from the annual reports of DNAMR (Direction Nationale de l’appui au monde rural) and DNSI (Direction Nationale de la Statistique et de l’Informatique). The text of this Section is based on the data given by CPS-MDR (2001).

The total cereal production in Mali varies between one and three million tons (Fig. 8.1). Millet and sorghum form the bulk, but the production of rice and maize has increased in recent years. When the total cereal production is plotted against annual rainfall, the relationship appears to be curvilinear (Fig. 8.2).

The production increases by about 60% if the rainfall goes up from 300 to 450 mm, but if the rainfall increases by another 150 mm there is hardly any additional effect on the total production. The cereal production is not simply a curvilinear function of rainfall, however, because there are several other qualifying factors. Five intervening variables can be mentioned:

- A part of the rice and wheat is grown in irrigated areas, so for these two cereals the effect of rainfall would be less pronounced than for the other crops.
- A part of the rice is grown on the floodplain and, as will be shown in this Chapter, this production is independent of rainfall, highly dependent on the flood level.
- The total cereal production has gradually increased over the years. Fig. 8.2 shows the production separately for the years before and after 1992. The effect of rainfall is evident in both periods, but the production has been raised to a higher level in more recent years. This increase is partly due to the extension and improvement of irrigation areas (Chapter 10 and 11) and partly due to the extension of the agricultural land. Within 16 years, the area on which rice is grown has almost doubled and the surface area for maize has even quadrupled.
- The general relationship shown in Fig. 8.2 for Mali as a whole differs per climate zone. The rainfall in the northern regions of Tombouctou or Gao is only a quarter of the rainfall in a southern region such as Sikasso (Fig. 2.4). Moreover, the lower the average rainfall, the larger the annual variation. Thus, the cereal production in the southern half of Mali fluctuates less than in the semi-arid half of Mali.

CPS-MDR (2001) gives the annual cereal production separately per region and this offers the opportunity to analyse whether the variable climate has a larger impact on the cereal production in the semi-arid regions than in the southern Sahel zone. Fig. 8.3 compares the effect of rainfall on the production for the region of Tombouctou, Mopti and Ségou. The average production is low in the dry Tombouctou region and high in the relatively humid region of Ségou. In all three regions rain has a large effect on the production. If rainfall is low, the production in Ségou goes down from 0.8 to 0.4 million ton and also in Mopti it halves from 0.4 to 0.2 million. The effect is most pronounced in Tombouctou where the production decreases from 0.1 million to nearly zero. The production in the three regions is not fully determined by the rainfall. There are irrigated areas in the region of Tombouctou (box 3.1) and a large part of the cereals produced in Ségou comes from the 740 km² of irrigated land in the Delta Mort (Chapter 11). The farmers in the Inner Delta may have a high production, even with less rainfall, as long as their land has been well flooded.

Fig. 8.2. Total annual cereal production in Mali (same data as Fig. 8.1) as a function of the annual rainfall. Source: CPS-MDR (2001). The inset figure shows the 28 meteorological stations that were used for the calculation of the annual rainfall. Sources: IER, ORS, ORM, etc.

Fig. 8.3. The total annual cereal production in the regions of Ségou, Mopti and Tombouctou as a function of the annual rainfall in the Sahel zone (same data as Fig. 8.2). Source: CPS-MDR (2001).

Rice production in the Inner Niger Delta

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Fig. 8.3. The total annual cereal production in the regions of Ségou, Mopti and Tombouctou as a function of the annual rainfall in the Sahel zone (same data as Fig. 8.2). Source: CPS-MDR (2001).
outside the Inner Delta and this was the same for sorghum: 21,000 of the 32,000.

The main conclusion from this Section is that rainfall has a large impact on the rural economy of Mali and that is still nowadays the case, despite the fact that an increasing part of the cereals are produced in irrigated areas. The next Sections will focus on the agricultural production of the floodplains. A part of millet and sorghum is grown during the crue or exposed floodplains, but since most of these crops are from outside the actual floodplains, we will restrict our analysis to the rice production.

8.3 Constraints in rice production

Farming is not easy in the Inner Delta and that is certainly true for rice farming. Experience is required to make it a success. This was clearly shown by Maïga et al. (2002) who found that within a same area, the traditional riziculteurs, the rice farmers being Rimaïbe, Chérif or Marka, always achieved a higher rice production per ha than the agro-fishermen (Bozo and Somono) and a much higher yield than the agro-pastoralists (Peul).

The farmers on the floodplain grow a West-African rice variety Oryza glaberrima, known as riz flottant or floating rice, which is well adapted to grow upwards with the rising water during the crue. However, ideally the seed should have been germinated before the flood arrives. That means that the farmers have to sow the rice grains before the first rainfall, in the hope that the rain comes before the flood and the rice has sprouted before the flood arrives. With the flood the depth of the water column increases by several cm a day. Rice plants are able to grow 3-4 cm a day following the crue. The stems may be as long as 5 metres, but usually they are about 2 metres long. After a flooding period of about 3 months, the rice can be harvested during the crue. A lot can go wrong in such a system:

- If there is no rain before the flood covers the floodplains, the seed has had no time to germinate before the area is covered by water.
- If there has been sufficient rain to sprout, the rice still needs water. That is why the flood must arrive not later than a fortnight after the last rains.
- If the timing and the amount of rain has been good, but the flood is low, the rice plant will grow, but the yield will be low due to the short growing season. A minimal flooding of 3 months is required.
- If there has been enough rain, but the flood is higher than expected, the production is lowered too. The optimal water depth is about 2 metres.
- Even if the growing of rice has been successful, the ripening grains must be protected later on against seed-eating birds, known with reason as ‘mange-milk’.

The annual peak flood level varies in the Inner Delta by about 230 cm on the gauge of Akka (Fig. 8.4). During the Great Drought the average peak level was 360 cm, while it was 580 cm during the long series of humid years before 1967. Given an optimal water depth of 2 m, rice should have been planted ideally at a level of 160 cm during the Great Drought and at 380 cm in the 1950s. Maybe more important than the depth of the water column is the duration of flooding. For each year, we calculated the water level at which an area is immersed for 3 months. As shown in Fig. 8.4, this level also varies annually, depending on the maximum water level. The level at an immersion of three months, \( y_{\text{mont}} \), is a function of the maximum water level, \( y_{\text{max}} \) (both in cm Akka):

\[
\frac{y_{\text{mont}}}{y_{\text{max}}} = 0.9225 - 1.0625 \times \frac{108}{y_{\text{max}}} \\
R^2 = 0.9225
\]

Equation 8.1 reveals that the minimal immersion time of rice is achieved if the water column is 85 cm deep at a peak water depth of 360 cm, decreasing to 71 cm at a peak level of 580 cm. That means that if farmers plant the rice in a zone being flooded by 1 - 2 m water, the flooding period is always long enough.

The farmers have to decide where they should plant their rice. Of course, they prefer to plant their rice on their own land being cultivated already for years. Nevertheless many farmers decided during the Great Drought to give up their traditional rice area and start to reclaim new ricefields lower down in the inundation zone. The people of Pora could indicate in the field precisely how, between 1973 and 1987, they successively removed nearly all flooded forests south of Kouakarou in an attempt to adapt themselves to the lower flood level. When the floods were higher again from 1994 onwards, they gradually moved back to the traditional ricefields. We heard the same stories from farmers elsewhere in the Inner Delta. Gallais (1967) already noted that the rice farmers are forced to be semi-nomadic due to the variation in flood levels. Of course the farmers cannot predict the flood level when they have to sow their rice. On the other hand, the flood level of the Inner Delta has shown over the last 80 years a long term fluctuation.
Rice production in the Inner Niger Delta (Fig. 2.5, Fig. 8.4), so the flood levels during the previous 5 or 10 years may therefore serve as a guideline in their decision where to cultivate their rice. The digital flooding model (Chapter 3) gives the opportunity to quantify this afterwards.

Fig. 6.3 shows the distribution of cultivated rice across the Inner Delta. In combination with the digital flooding model, it was possible to indicate that in the season 2002/03 the ricefields were found at a level between 200 and 400 cm relative to the gauge of Akka. The average maximum water depth was 470 cm in the previous five years and since the ricefields in that period were situated in the same areas, we conclude that in the late 1990s, the average water depth in the rice fields was 178 cm when the flood was at its maximum level.

The distribution of ricefields is also known for 1952, when aerial photos were taken on which the topographical maps of IGN were based. The ricefields, such as indicated on topographical maps, were digitized and combined with the digital flooding model. The same was done with the data of Marie (2002) who gives a map of the ricefields in 1987. The ricefields in 1952 and 1987 are shown in Fig. 8.5. It is clear that the ricefields in 1952 were more on the fringe of the southern Delta and those of 1987 further inside. The elevation of the ricefields, relative to the gauge of Akka, is given in Fig. 8.6. Most of the rice fields in 1952 were cultivated at a level of 230 – 360 cm and in 1987 at 310 – 410 cm. So, while the flood level was 220 cm lower, the farmers moved down about 80 cm. As a consequence, the rice was covered with much less water in 1986 than in 1952.

Fig. 8.7 converts the data from Fig. 8.6 to show the water depth on the ricefields. In 1987 the rice grew in 47 cm of water and the flood did not cover a quarter of the ricefields at all. In 1952 and 2003 rice was covered by 178 and 149 cm (median values).

After a series of five low floods why did the farmers not grow their rice in the 1980s further down in the inundation zone? Several answers can be given:

- The farmers remained optimistic and hoped that the flood would be better next year.
Table 8.1. Six estimates of the surface area of land being cultivated for rice in the Inner Delta.

<table>
<thead>
<tr>
<th>Year</th>
<th>Surface, km²</th>
<th>Source</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>1920</td>
<td>150</td>
<td>Gallais 1967</td>
<td>Field visit</td>
</tr>
<tr>
<td>1935</td>
<td>645</td>
<td>Gallais 1967</td>
<td>Field visit</td>
</tr>
<tr>
<td>1952</td>
<td>790</td>
<td>Gallais 1967</td>
<td>Field visit</td>
</tr>
<tr>
<td>1952</td>
<td>&lt;1648</td>
<td>IGN</td>
<td>Aerial photos</td>
</tr>
<tr>
<td>1987</td>
<td>1590</td>
<td>Marie 2002</td>
<td>Remote sensing</td>
</tr>
<tr>
<td>2003</td>
<td>&gt;1040</td>
<td>This study</td>
<td>Remote sensing</td>
</tr>
</tbody>
</table>

Fig. 8.8 shows the surface area of the zone with a water depth of 100 to 200 cm as a function of the peak water level in Akka. At a water level of 580 cm, 4300 km² would be suitable for rice cultivation regarding the water depth. This decreases by 80% to 800 km² at a flood level of 360 cm. Marie (2002) already did the same kind of calculations and also concluded that there was a reduction in the potential rice habitat at a lower flood level. Marie (2002) also compared the total surface area of actual ricefields to the calculated surface area of the zone with an optimal water depth. His conclusion was that not all the habitat having an appropriate water depth is suitable for growing rice. Rice does not grow well, for instance, in sandy bottoms, being less fertile than clayish substrate. It is not without reason that the cultivated rice area is concentrated in the southern part of the Delta (Fig. 8.4), where the clay content of the substrate is rather high. Farmers in the Inner Delta do not use artificial fertilizers, so they depend on ground with a natural fertility. The digital flooding model should therefore be integrated with scattered information about soil (e.g. Makaske 1998) and nutrients (e.g. Orange 2002b) to show the absolute limitations to a further extension of the cultivated rice area given different flood levels.

The surface area of rice cultivation has increased during the last 80 years (Table 8.1). The figures in Table 8.1 are not fully comparable. The estimated surface area for 2003 is relatively low, since all bare areas within ricefields or areas being covered with grass, are not reckoned as ricefields. In contrast, these areas are included by Marie and on the IGN map. This presumably also explains why the estimate of Gallais (1967) for the same year is much lower. The trend is clear, however: the surface area of the ricefields has increased during the last 80 years. This increase may be explained by the increase of the human population (Marie 2002). In 1957, there were 78,000 rice farmers and, including women and children, 170,000 people depended on rice cultivation for a living. In 1987, the population had doubled to 340,000 and also the cultivated area was twice as large (Table 8.1). Hence, the area per person had remained the same at about a half ha per person. Since, on average, the yield has also remained constant during the last 50 years at about 1000 kg/ha (Gallais 1967; annual reports of DRAMR), the rice production per person, although varying from year to year, has also remained at a similar level.

Marie (2000, 2002) gives three other estimates for the cultivated rice area in the southwestern part of the Inner Delta: 596, 986 and 770 km² in 1952, 1975 and 1989 respectively. This suggests that during the Great Drought the increase in the surface area of rice cultivation has come to an end, or that there was even a temporary decrease.

Taking all information together, it is obvious that the rice farmers in the Inner Delta increasingly compete for good areas to grow rice. The lower flood levels in recent times only aggravate the situation. Marie (2002) and Moseley et al. (2002) both point to an important implication. If farmers start to grow rice lower in the inundation zone, they have to remove existing bourgou fields. Bourgou grows in deeper water than rice, so the rice farmers will remove the most shallow bourgou fields. As discussed in Chapter 7, bourgou is a highly productive plant, being essential for the survival of very large numbers of cows. This implies that farmers growing rice and farmers raising cattle are in competition with each other and that this competition increases with a reduction of the flood level.

### 8.4 Annual rice production

Rice farmers in the Inner Delta produce on average 86,000 tons of rice, but there is a large variation from year to year (Fig. 8.9). The farmers themselves consume almost all the rice and only a small part is sold. Kuper & Maïga (2002), who did an extensive and excellent study on the trade of rice within the Inner Delta, concluded that in good years no more than 10% is traded and that this reduces to almost nothing in poor years. The study of Kuper & Maïga (2002) was partly based on the annual statistics obtained by the DRAMR in Mopti. Our analysis is also based upon the annual reports of DRAMR-Mopti since 1987, but also on the reports of DRAMR in Tombouctou. The analysis could be extended over a longer period because the Operation Riz Ségou (ORS) has published annual reports since 1970, in which all their essential rural statistics have been recorded. The annual reports of Operation Riz Mopti (ORM) appear since 1981.

Fig. 8.9 shows the annual variation in the production of rice in non-irrigated fields in three areas: the area managed by ORS and by ORM and the floodplains in the region of Mopti. DRAMR distinguishes areas where rice is grown in different ways (Table 8.2). Fig. 8.9 shows the annual variation for three of the eight categories given in Table 8.2; the three are printed in bold. Irrigated rice fields are excluded from the figure, since we are interested in the variation in rice production in relation to rainfall and flood level and both factors have hardly any or no effect on the rice production in actively irrigated fields. There are a few large irrigated areas in the region of Tombouctou, in total about 110 km². The production is substantial: 36,000 – 45,000 tonnes and also the yield is high with about 4000 kg/ha. In...
the region of Mopti, there are several small, irrigated areas near villages. The total surface area is altogether 16-27 km² with a total production of 6,000-16,000 tonnes and a yield of 5700 – 6000 kg/ha. Unfortunately we do not have the complete data set of the rice cultivation on the floodplains of the region Tombouctou, so they are not included in Fig. 8.9 or in the further analysis. Riz de bas fonds is cultivated in the region of Tombouctou on 37 – 40 km²; production 900 – 1900 tonnes, giving a yield of 380 – 560 kg/ha. Riz de désâtre is cultivated in the northern lakes on 85 – 106 km²; production 7,600 – 13,000 tonnes and the yield is: 1300 – 1500 kg/ha.

The total production of non-irrigated ricefields in the Inner Delta fluctuates between 40,000 and 200,000 tons but, as could be expected, the production of the irrigated fields does not vary much and amounts to 40,000 to 60,000 tonnes. In the next three Sections, we analyse the rice production by ORS, ORM and the production of riz à submersion libre in the region of Mopti in relation to local rainfall and flood level.

### Rice production by Opération Riz Ségou (ORS)

ORS manages three areas: Markala 53 km²; Dioro 150 km² and Tamani 152 km², in total 354 km². It is situated along the Niger River east of the town of Ségou, in the cercles of Ségou and Barùéli (Fig 8.5). There are over 200 villages in the area of ORS with 200,000 people. There is no active irrigation. There are dikes and sluices to delay the flooding, if necessary, and to manage the water level during the décrue. Hence it is a polder, a ‘basin’, but the water management is passive. If the flood does not rise high enough, the area remains dry. That means that the agricultural production will only depend on local rain and the flood of the river.

The local rain is well registered. ORS measures the rainfall in 14 stations. We calculated the average of 6 stations with (almost) complete series since 1982; unfortunately no rainfall data are available for the years before. For flood level, we take the peak flood level of Mopti. Of course, Mopti is downstream of the ORS area, but given the close relationships between the peak flood levels measured at different places, the measurements of Mopti can be used as a good indicator of the annual flood level.

The total annual production during the last 35 years varied between 2,086 tonnes in 1984/85 and 55,718 tonnes in 1976/77 and amounted to an average 12,021 tonnes. Of the 350 km² available, on average 240 km² is annually cultivated for rice growing, of which 171 km² produces, on average, enough rice to be harvested. That means that, on average, the annual production in the cultivated rice area is 932 kg/ha (see Table 8.2).

The ORS-annual reports clearly show that the huge variation in production is caused by a highly variable part of the area with crop failure and also to a large variation in the yield of the area being harvested. The surface area being cultivated without any harvest varied between 5 and 82%. The average yield in the harvested area also varied per year, but less, between 945 kg/ha to 1750 kg/ha.

The variation in productivity is related to the flood level (Fig 8.10). The black regression line shows the calculated relationship: the production increases by 137 tons if the peak water level goes up one cm. This function is based on all the data. When the data are split up for years with low rain (<400 mm) and much rain (>600 mm) and average conditions in between, it is clear that the production is always low if the rain is limited (see the purple dots in Fig. 8.10). All years with exceptionally high production have much rain, but there are also rainy years with a low production. When the years with low rain (<400 mm) and much rain (>600 mm) are taken apart, the flood levels still have a dominant effect on the production (see yellow line and yellow printed function).

There is still variation around the yellow regression line shown in Fig 8.10, so there are, apart from flood level and rainfall, still other factors, such as the timing of the rainfall and the timing of the flooding that may influence the annual rice production. Another possible factor might be the variable amount of artificial fertilizer used. Until 1988 no or hardly any fertilizer was used in the area of ORS but since then there has been an exponential increase to 2145 tonnes in 2004. When the amount of fertilizer annually used is plotted against the deviation from the regression line, we found no relationship. Moreover, the average yield has not increased during the last 20 years. We conclude from this that rain explains a part of the observed huge variation in annual rice production in the ORS area, but that flooding is the major factor.

#### Table 8.2. The rice production (x 1000 tons) in three regions and in five types of ricefields. The given range refers to the minimum and maximum production during four seasons (1999/2000 – 2002/2003). Fig. 8.9 shows the annual production for three categories (bold printed). Source: DRAMR-Mopti and DRAMR-Tombouctou.

<table>
<thead>
<tr>
<th>Region</th>
<th>Ségou</th>
<th>Mopti</th>
<th>Tombouctou</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigé, irrigated ricefields</td>
<td>6-16</td>
<td>36-45</td>
<td></td>
</tr>
<tr>
<td>Submersion contrôlée, polders of ORS and ORM</td>
<td>23-37</td>
<td>1-24</td>
<td></td>
</tr>
<tr>
<td>Submersion libre, rice grown on the floodplains</td>
<td>19-116</td>
<td>5-10</td>
<td></td>
</tr>
<tr>
<td>riz de bas fonds, rice grown in depressions</td>
<td>1-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>riz de désâtre, rice grown in immersed area (lakes)</td>
<td>8-13</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 8.3. Average surface area, yield and number of farmers in the rice areas managed by Opération Riz Ségou (ORS; 1973–2002) and Opération Riz Mopti (ORM; 1981–2002).

<table>
<thead>
<tr>
<th></th>
<th>ORS</th>
<th>ORM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total surface, km²</td>
<td>350</td>
<td>330</td>
</tr>
<tr>
<td>Cultivated area, km²</td>
<td>240</td>
<td>183</td>
</tr>
<tr>
<td>Harvested area, km²</td>
<td>171</td>
<td>85</td>
</tr>
<tr>
<td>Total production, tonnes</td>
<td>22,022</td>
<td>10,593</td>
</tr>
<tr>
<td>Yield cultivated area, kg/ha</td>
<td>921</td>
<td>616</td>
</tr>
<tr>
<td>Yield harvested area, kg/ha</td>
<td>1290</td>
<td>1079</td>
</tr>
<tr>
<td>Number of farmers</td>
<td>12,546</td>
<td>11,133</td>
</tr>
</tbody>
</table>

Rice production by Opération Riz Mopti (ORM)
The area managed by ORM has the same kind of infrastructure as the ORS. The farmers also depend on the peak level of the flood and the local rain. The area managed by ORM thus confirm the conclusion drawn for ORS that flooding is the major factor determining the rice production in the flooded oases.

Rice production on the floodplains of the Inner Delta
The data of ORS and ORM concern the rice production within a limited area of 680 km². If the flood level is not sufficient to flow into this area, the rice harvest is very limited. One may argue that the farmers in the Inner Delta might do better, since they have more opportunities to move down to the lower inundation zone in years with reduced flood levels. According to the annual reports of DRAMR the area cultivated by rice farmers in the region of Mopti has gradually increased from 1000 km² to 1200 km² in recent years. The yield is highly variable and also in a good year not higher than about 1000 kg/ha. Fig. 8.12 shows the relationship between the total production with the flood level in Mopti. The data are split up for more or less than 400 mm rain, using the same data set as we already used for ORM. The picture is similar to Fig. 8.12. If there is less rain, the production decreases with 10–20,000 tonnes, but the impact of the flood level is much more pronounced. During a low flood the production is only 20,000 tonnes, but this increases to 60–120,000 tonnes at a high flood.

Rice production per cercle
It is obvious that the rice production decreases at lower flood levels. One may expect that this negative effect is maximal for ricefields found higher in the inundation zone. Since the ricefields in the cercles of Ténénkou, Djenné and Mopti are found at a higher level than the ricefields in Youvarou, the impact of...
lower floods should also be different when cercles are compared. Fig. 8.13 shows the total production for ORS and the nine cercles of the Inner Delta during three years with a relatively high flood level and one with a low level. The rice production in the three years with a high flood did not differ much and also the share over the cercles and the ORS area was about the same. When the flood is high, most rice in recent years is grown in the cercle of Mopti (inclusive ORM and ORS) has been related to Akka water level (Fig. 8.14). Due to a lack of data the figure only shows the rice production for the seasons 1987/88 to 2002/03. Within those years the total annual production varied between 10,600 and 115,700 tons. Fig8.14 gives the production of ORS, ORM and floodplains of Inner Delta combined.

The impact of flood level on the rice production in the area of ORS, ORM and on the floodplains is evident (Fig 8.10 - 8.12). Hence the impact of the reduced flood levels due to Selingué, Office de Niger and Fomi on the rice production may be quantified. The peak water level at Sofara or Mopti was used as a measure of the flood level in Fig 8.10 - 8.12, but we use the flood level in Akka as an indicator of the flood level in our scenarios. That is why the impact of the dams on the entire rice production in the Inner Delta (including ORM and ORS) has been related to Akka water level (Fig. 8.14). Due to a lack of data the figure only shows the rice production for the seasons 1987/88 to 2002/03. Within those years the total annual production varied between 10,600 and 115,700 tons. Fig8.14 gives the production of ORS, ORM and floodplains of Inner Delta combined.

Using the combined regression function of rice production against peak flood level in Akka (shown in black in Fig 8.14), the effect of Selingué, Office de Niger and Fomi can be indicated (Fig 8.15). On average, the lower flood due to Selingué causes a reduction in the rice production of 8900 tonnes or 10.4%. The impact of Office de Niger is larger: 4300 tonnes or 4.9%. Fomi would reduce the rice produc

production varied between 10,600 and 115,700 tons. Fig8.14 gives the production of ORS, ORM and floodplains of Inner Delta combined.

A multiple regression analysis was performed to see whether we could obtain one function in which the combined effect of rainfall and flood level could be shown. Rainfall was not significant. Also the relationships shown in Fig 8.10 to 8.12 showed a (highly) significant effect of the flood level, but that rainfall had no significant effect.

Using the combined regression function of rice production on the two levels of rainfall. Source: DRAMR, ORM and ORS.

Chapter 13 will integrate the evident negative effect of the upstream infrastructures on the rice production on the floodplains. Two remarks can already be made. First, the 200,000 tonnes of rice produced since 1987 with irrigated river water in the area of Office de Niger, is only possible at the expense of a reduced flood level in the Inner Delta, by which the farmers face an annual loss of 4300 tons. This loss in the Inner Delta was equivalent to 5% of rice production of Office de Niger in the late 80ties. The rice production at Office de Niger has increased (Chapter 11), while the amount of water taken has remained at the same level (Chapter 2). That is why the loss of rice production in the Inner Delta due to Office de Niger has decreased to 1.8% relative to the recent production of Office de Niger. This changes the cost-benefit analysis, but this does not matter to the farmers in the Inner Delta.

The second remark is that the rice production in the Inner Delta is regularly insufficient to feed the local people. According to Randolph (1995) the people in Mali eat per person and per year 30 kg of rice and 120 to 150 kg of millet and sorghum. The people in the Inner Delta consume 80 kg rice and less millet and sorghum. The population in region of Mopti has increased between 1987 and 1998 from 570,000 to 630,000 people (Table 6.1). The ORS area is cultivated by 15,000 to 17,000 farmers, thus including their families, the rice they grow must be sufficient to feed 60,000 to 70,000 people. In total 200,000 people live in the ORS-area. Given an auto-consumption of 80 kg of rice for 760,000 - 840,000 people, this would result in an annual consumption of 61,000 to 67,000 tonnes. Since 1987, the actual production has been below this level in 4 out of the 16 years. This would have been 10 out of the 16 years, if the Fomi dam had reduced the flood level and hence the rice production.
8.6 Conclusions

- As in other Sahel countries, the annual rainfall has a dominant effect on the rural economy of Mali, especially in the drier part of the country. The production of millet, sorghum and rice decreases sharply if the annual rainfall in the Sahel zone decreases to below the 400 mm.
- The rice farmers in the Inner Delta are also dependent on rain in the weeks before the flood covers their ricefields, but the production is mainly determined by the flooding. The rice variety being used on the floodplains grows with the rising water and needs coverage by water for 3 months. Most rice is cultivated in areas being inundated by 1 – 2 metres.
- During the Great Drought, the flood level decreases by 2.2 metres. Farmers started to grow rice further down in the inundated area. On average, they moved down 80 cm, by which the inundation of rice decreased by, again on average, 140 cm. This is the main reason why the rice production falls during the periods of low floods.
- At low flood levels the farmers in the Delta did not move lower down in the inundation zone, because there was not sufficient area suitable for rice cultivation at such low water levels.
- The rice production in the area of Opération Riz Ségou, Opération Riz Mopti and on the floodplains of the Inner Delta varied from year to year. This variation could be attributed to flood level and to a lesser degree to rainfall. In total, the average production amounted to 83,000 tonnes, but at a low flood this reduced to 10,000 and if the flood is high to 80,000 to 120,000 tonnes.
- Since the rice production on the floodplain and in the flooded polders is strongly related to the peak flood level, the impact of the reduction of the water level due to the dams or irrigation can be reasonably well indicated. Due to Sélingué, the farmers produce, on average, 8900 tonnes,