REPORT ON A VISIT TO NIGER

12 - 25 June 1994

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INTRODUCTION

1 This report describes a short visit made by the writer to the Republic of Niger in June 1994. The terms of reference of the visit are given in Appendix A. The primary purpose was to review progress in the project PMI-Niger (Irrigation Management Project, Niger) and to offer ideas and recommendations for its future stages. PMI-Niger is a collaborative project between the International Irrigation Management Institute (IIMI) and the Government of Niger, and is financed by the African Development Bank.

2 Visits were made to three of the project's four field sites : Kourani Baria I and II on 21 June, and Saga on 22 June. The fourth site, Tillakaina, had no irrigation activity at this season and was not visited on this occasion. The rest of the time was spent in discussions and in reading the reports and other outputs prepared by the project team. A full list of documents reviewed is given in Appendix B.

3. Some administrative and budgetary issues were raised by IIMI headquarters just prior to the visit, and time had to be spent, unexpectedly, on resolving these. In consequence, the time available for devoting to the professional issues raised in the Terms of Reference was somewhat curtailed, and not all of those matters could be successfully covered. This is regretted, but a follow-up visit has been arranged to take place in October 1994, when the remaining items will be completed.

PROJECT GOALS

4 PMI-Niger is a project of four years' duration. It was begun towards the end of 1991 and is expected to end at the end of 1995. The project team consists of Nigérien staff seconded from national agencies for the purpose, headed by a member of IIMI's international staff. The principal national agencies involved are ONAHA (Office National pour les Aménagements Hydro-Agricoles:

National Office for Irrigation Systems) and INRAN (Institut National de la Recherche Agronomique du Niger : National Agronomic Research Institute of Niger).

5 The project addresses questions about the management of irrigation systems along the valley of the River Niger. These are all pumped systems, close to the river. The majority of them are rice producers. A list of all schemes, drawn from the ONAHA Annual Reports, is in Appendix C. There are 33 rice-based river-pumping systems along the 470 km of the Niger River within the Republic. Their total area is 7905 ha, and so their average size is 240 ha.

6 The project document (reference 1) gives the following objectives for the project :

a to reinforce ONAHA's capacities and skills in carrying out its role of providing support and advice to co-operatives in irrigation management;

b to reinforce INRAN's capacities and skills in analysing production systems, particularly those aspects related to irrigated and rainfed cultivation;

c to strengthen the research-development-training linkage by establishing close co-operation with the Faculty of Agronomy of the University of Niamey.

The project document also states the overall goal of the project as:

- to increase food production and farm incomes in order to maintain the farmer on the land, promote the independent management of irrigation schemes by farmers, promote and develop female labour on irrigation schemes, and protect the environment, the production potential (soils) and the investments made in irrigation.

7 The project document states the expected results of the project as follows:

a the development of a method for analysing the management and operation of the irrigation schemes of the river valley, and for evaluating their performance;

b the formulation of concrete and reliable recommendations for improving performance in the following areas : technical management of water distribution systems (efficiency, equity, reliability); development of irrigation (diversification of crops); utilisation of the irrigation schemes (intensification); organisation and efficiency of the transfer of management responsibility to producers;

c the definition of a set of technical and socio-economic recommendations for rehabilitating the irrigation schemes of the river valley (agricultural credit and water rate policies, ways to enable farmers to participate in the management and upkeep of the irrigation schemes);

d the establishment of a long-term training programme that is based on individual actions and on group sessions and that is designed to provide vocational training in irrigation management and in the operation and upkeep of irrigation systems, as well as a continuous programme of training for farmers on the pilot sites;

e the preparation of a practical guide in vernacular on irrigation management intended for producers and managers of irrigation schemes in farmer organisations.

8 These are large and ambitious aims. In this report I am concentrating on items (a) and (b) of paragraph 7 above, the analysis of scheme performance and the generation of a set of recommendations for performance-enhancing actions by government or by farmers.

FEATURES OF NIGÉRIEN RICE IRRIGATION

9 The majority of Nigérien irrigation systems are oriented towards rice production. The project studies three rice-producing systems and one non-rice system (see paragraphs 24 to 34 below). In this section some characteristics of Niger's rice irrigation systems are discussed, in order to identify problems which the project may be expected to address.

10 Rice is not a highly significant crop in the total food supply of Niger. Figure 1 shows the average pattern of cereal production for the five years 1987-1991. Rice represented on average 3.8% of total cereal output, and production and consumption of rice per person, at 6.2 Kg and 12.2 Kg respectively in 1988-90, are among the lowest in West Africa.

11 The demand for rice has however been increasing, especially among the urban population. The government began to promote the construction of rice irrigation systems in the 1960s. Of 36 irrigation systems along the river, 4 were installed in the 1960s and 13 in the 1970s. In the 1980s there was further impetus due to the rehabilitation of most of these earlier schemes, and the addition of a further 14 new ones.

12 Even with these additions, national production has not increased as fast as demand, and, in recent years somewhat more than 50% of the rice consumed in Niger has been imported, at yearly costs in the order of US$20-30 million.

13 Figure 2 shows the recent history of demand and supply and Figure 3 the output of the river lift irrigation systems.

14 A major reason for promoting cultivation of irrigated rice has been its relatively stable production levels, in an environment where the rainfed production capacity varies greatly and unpredictably from year to year. FAO data indicate that the coefficients of variation of the annual outputs of millet and sorghum, the principal grain crops, are about 25%, whereas for irrigated rice this statistic is stabilised at only about 10%.

15 Yields of rice obtained on irrigation schemes are not unsatisfactory. According to ONAHA's records, the average yield obtained in 1992 was 4.76 t/ha, and in the wet season 4.48 t/ha, for an aggregate of 9.24 t/ha/y. The lower yield in the wet season is partly due to waterlogging difficulties experienced on some systems, and partly to varietal differences. The yields obtained could be improved, perhaps up to levels of the order of 12 - 12.5 t/ha/y; but in view of the financial difficulties for farmers to afford inputs in an economy such as Niger's, the figures actually being achieved seem quite good.

16 Crop intensity also is sustained at quite high levels. In 1992 the intensity of rice planting was 86.8% in the dry season, and 82.4% in the wet season, making 169.2% overall. So, in this factor also, some improvement is possible, but not a large amount: the improvement could not be more than about 15% on average.

17 The problems faced by Nigérien rice irrigation systems are on the financial and institutional side, rather than in regard to production. The costs of production are quite high, and it is not easy to meet those costs. The government, especially since 1982, has been trying to reduce its own payment of these costs, and to transfer them to the farmers. As a vehicle for this policy, as well as to enable the farmers to arrive at their own decisions independently, the government has promoted the formation of co-operative organizations on each irrigation system.

18 Each co-operative has a sub-structure of GMPs (Groupements Mutualistes des Producteurs: Farmers' Co-operative Groups). On average, a GMP has 107 members, who cultivate 45 hectares. The members of each GMP are supposed to elect their own leaders, who in turn choose representatives to the co-operative's committee, as described later for the case of Saga irrigation system. The GMP looks after water distribution and some other field activities. Finance is the concern of the co-operative.

19 ONAHA provides a technician who acts as the system manager. ONAHA also provides other services, and charges the co-operative for them. The co-operative is expected to pay all costs of irrigation, and to put aside funds into a depreciation or renewal account so that it will itself have the capacity to renew major equipment when the life of existing items of equipment has expired. The co-operatives also all face substantial bills for energy, since these are all pump systems.

20 It has not proved easy to make this system function smoothly. The basic problem is that the farmers' earnings from rice cultivation have been low, and so the seasonal irrigation fees to be paid by the individual farmer take a large proportion of the farm income.

21 The price of rice, until 1994, has been weakened by competition from imported rice. The price paid by RINI (Société du Riz du Niger : Niger Rice Agency) has been around FCFA 65-70 per Kg. (FCFA 1,000 = 20 French francs = US$3.64). However the devaluation of the CFA franc by 50% in January 1994 has doubled the price of imported rice. The effects of this upon the total economics of Nigérien irrigation are not yet clear. However it is certain that locally-produced rice can now be competitive at substantially higher price levels, and the private-sector rice market is therefore now offering farmers rewards that are significantly better than they were. Whether this will improve the finances of the co-operatives is an important question which should be resolved quite soon.

22 The role of non-rice crops in the rice-based irrigation systems in Niger is small, and is confined to the dry season. Certain horticultural crops are profitable, but local demand is small at present, though probably it is growing. It seems likely that one of the effects of the currency devaluation will be that most farmers will continue to grow rice in both seasons for the immediate future.

23 Since the irrigated lands are all quite close to the river, flood damage in the wet season is a common difficulty. The region is semi-arid, and therefore rainfall and runoff events, when they occur, can be very intense. Surface drainage systems exist, but cannot easily cope with such events.

PROJECT SITES AND ACTIVITIES

24 The project aims to achieve its objectives by studying a small set of four irrigation systems, and obtaining from these, lessons which should be applicable to the management of all or most of the other systems. The project's activities are arranged in two major components : (i) research; (ii) training and information. This report discusses mainly the research component, in accordance with the writer's terms of reference as given in Appendix 1.

25 The chosen four systems for the research component are Saga, Kourani-Baria I, Kourani-Baria II and Tillakaina.

26 Saga is one of the older systems. It was established in 1966, and rehabilitated in 1987. It consists of about 395 ha, divided into 7 GMPs. The exact area of it is not quite clear. It was intended to irrigate 431 ha, but in recent years the actual area irrigated for rice has been about 380 ha. This does not mean that the other 51 ha have all been abandoned. A significant amount of these lands are now used for non-rice crops : fruit trees or dry-season vegetables. The standard size of land holding is 0.25 ha. There are 1081 users at present : about 66% of them have just a single standard holding, while 34% have more than one. Approximately 50% of the farmers have some horticultural land as well as their rice fields. 68% of them have rainfed land as well; the median extent of this is about 1.25 ha.

27 Saga may be different, in socio-economic terms, from other Nigérien irrigation systems, because it is very close to Niamey. This proximity probably has three particular effects : the profile of the farmers is different (more literate, and possessing more resources and more influence) from would be found at a

more remote place; there may be problems of social cohesion because of the varied origins of the farmers; and it is easier to make farming profitable, than it would be elsewhere, because input prices are lower and output prices higher, at a peri-urban location. Niamey contains about 10% of the population of Niger.

28 The 7 GMP districts of the Saga system were not all constructed initially. The system grew gradually over many years. Land allocation policies varied during that time, so the composition of the GMP farmer communities is not the same.

29 Saga draws all its water through one pumped station, with electrically-operated pumps. There is a second-stage pump station which lifts water further to the upper parts of the scheme. The decision about how long to operate the pumps in the main station each day is obviously critical in respect of costs and benefits.

30 Kourani-Baria I and Kourani-Baria II are newer schemes. They lie on the right bank, about 100 km upstream of Niamey, and nearly opposite the regional centre Tillabéri. The schemes are adjacent but rely on two different pump stations; however the pump station of Kourani-Baria II (which is downstream) serves a drainage function for both systems. Each system has its own co-operative.

31 Kourani-Baria I was established first, in 1986. It has 425 ha, divided among 9 GMPs, and 1032 farmers.

32 Kourani-Baria II, established in 1989, has 268 ha, 5 GMPs, and 656 farmers.

33 Both of these systems suffer drainage difficulties. Kourani-Baria I is traversed by a large ephemeral watercourse. Kourani-Baria II has land-level and gradient problems that make certain areas vulnerable to water-logging.

34 The fourth system, Tillakaina, is a non-rice system of 86 ha. It is not under consideration in this report, as it is operative only in the main dry season, and does not grow rice.

35 The project activities, up to the present time, have been focussed primarily upon Saga, and to a lesser extent Tillakaina. Kourani-Baria I and Kourani-Baria II were the subject of a joint rapid appraisal in 1992 but have had a lesser share of attention since then. It was reasonable for the team to establish their methodology first on the easily accessible site of Saga; however, Kourani-Baria I and Kourani-Baria II are probably more representative than Saga, in respect of the complete set of Nigérien rice irrigation systems, so it seems desirable that, from now, the two Kourani-Baria systems should be the principal focus of the project team.

36 Field activities up to now have consisted mainly of data collection in order to develop comprehensive descriptions of the processes occurring in the systems. In order to accomplish the aims (b) and (c) of the project (see paragraph 7 above) the team must now move on from the data-gathering or descriptive phase, and enter the analytic or explanatory phase in which a logical framework, adequately explaining the causation of the observed processes and performances, will be developed. This phase has been started by the team, with the drafting of several reports about the Saga system in recent months (references 6, 7, 10, 11, 12). The final phase of formulating recommendations for intervention or change in the systems, cannot safely be attempted until the explanations of what is occurring at present have been developed. It seems clear, therefore, that much work has to be done, especially in respect of Kourani-Baria I and Kourani-Baria II, in order to complete all phases of description, explanation and recommendation within the 1½ years now remaining.

WATER

37 Most of the project's work on delivery and utilization of water, up to now, has been done in Saga and in Kourani-Baria I. In Saga, which has been more intensively studied, the team has investigated three levels of water supply : supply to the whole system; distribution among the secondary canals; and distribution among the tertiary canals along a secondary;

38 In order to verify whether supply is adequate for crop needs, calculations of crop water requirements have been made, using Penman estimates of evapotranspiration plus conventional approximations about such aspects as effective rainfall, seepage, land preparation and conveyance efficiency whose real values are not accurately known. It would be desirable to verify these calculations with visual observations of field wetness. There is a quite significant amount of literature about this (e.g. Wijayaratna 1986) as a cheap and reliable method of assessing adequacy and equity of water distribution in rice systems. It is more reliable than methods based on theoretical calculation of water requirements, because those methods need to incorporate assumed coefficients which are often not very accurate.

39 Overall consumption of water in Saga is estimated according to the record of numbers of Kilowatt - hours of energy used by the pumps each day. Figure 4 and Table 1 show, for nearly four complete seasons, the relationship between the monthly amounts actually pumped, and two different demand values, which are the calculated monthly potential evapotranspiration, and the project's estimate of total water requirements. The project estimate includes a crop stage coefficient, conveyance efficiency coefficient, estimates of additional water for land preparation, and for seepage, and of water reductions in the wet season due to effective rainfall.

40 The amounts actually pumped are determined by the demands of the representatives of the 7 GMPs. They notify the pump operator, daily, about the water requirement of their zones. The pump operator informed us that he fixes his pumping hours according to their demands. However it is not clear how this calculation can be done by the operator.

41 Figure 4 shows that, in the months when corrections for land preparation and effective rainfall are unimportant (that is, January to April, plus October), the amount of water pumped has a consistent relationship to potential evapotranspiration. Figure 5 shows that potential evapotranspiration accounts for about 70.2% of the amount of water pumped at the main station in those months.

42 That indicates that the overall efficiency of the water delivery and application system is 70.2%. This confirms the project team's assumption. It is a quite satisfactory figure for a partially-lined rice system.

43 Figure 4 also shows that the project's assumptions about water requirements are significantly higher than the actual pumping rates, especially in the dry season. On average, the actual pumping based on requests by the GMP representatives is 85.5% of the project estimates of water requirements.

44 This could mean either that the project estimate is too high, or the GMP representatives' requests are less than what is really needed. I think the second of these explanations is not very likely; but it can be verified, as discussed above in paragraph 38, by observing whether the fields remain wet. Certainly, if the amount pumped is only 85% of the true requirement, many fields will be frequently without visible standing water.

45 It seems more likely that the project estimates are too high, probably because the crop coefficients and land preparation allowances are too big.

46 The degree of agreement shown in Figure 5, between the demands of the GMP representatives and the actual crop requirement, is close. It suggests that the Saga GMP representatives are quite good at estimating the requirements. I recommend that the project team should find out what procedures they use, and also that the team should verify how the pump operator uses their information in order to decide the total hours of pumping each day.

47 Figure 6 and Table 2 show how the pumping quantities at Kourani-Baria I compare with potential evapotranspiration. The overall efficiency of the water system, calculated in the same way as was done for Saga in paragraph 41 above, is 52.2%, which is not as good as the 70.2% found at Saga. It is not clear whether physical reasons such as soil infiltration rate, or organizational reasons are more likely to explain this. However the co-operative and the GMPs at Kourani-Baria I are new, so they do not yet have the level of experience which is available at Saga.

48 Next we may consider the second level of water management, which is distribution of the pumped water among land units in the irrigation system. In Saga, the project has not looked in detail at the way in which water is distributed among the 7 GMPs. It has concentrated attention on a lower level of distribution, the operation of the secondary canal S2P1 which delivers water to GMP 2 and GMP 3. Locations of these GMPs are shown in Figure 7, and the position of canal S2P1 and other secondaries in the canal layout is in Figure 8.

49 Although the water distribution among GMPs has not been closely monitored, some data about discharges into the secondaries are available from a few days' measurement in April 1992. From these measurements it seems that S2P1 was able to carry a discharge of at least 450 l/s, which (when compared with the design discharge of 470 l/s) suggests that the canal size is adequate for good water management. However it would be desirable to conduct some more detailed measurements at this level, in which total water delivery per day would be measured in each secondary, and these would be compared with the requests for water made by the GMPs.

50 At the moment, although we know the total amounts delivered to the whole system each month, we do not know enough about the variation of these deliveries in time or in space. Therefore, we cannot yet say much about the effectiveness of existing overall water management arrangements. Figure 15 shows the average yields of paddy obtained in each GMP in the wet season of 1993 : they do not vary very greatly, and their coefficient of variation is about 8%. Perhaps the system by which GMP representatives express their water needs is quite adequate; perhaps it is not; perhaps it needs some small improvements. We do not know at present. Since this question concerns the effectiveness of the existing institutional system (that is, the effectiveness of the GMP, which is the first organizational level), it must be investigated by the project.

51 The daily record of actual pumping, maintained by the pump operator, should also be studied by the project team. Figure 9 shows a short extract from the record book. It varies greatly within a few days. It is not likely that crop water demands really varied as much as this, so it seems as if there must be other factors affecting the operator's procedures.

52 The canal S2P1 which has been the subject of detailed studies has a nominal capacity of 470 l/s. It supplies water to 15 tertiaries, 7 in GMP2 and 8 in GMP3. All are on the right bank. The area supplied in GMP2 is 49.5 ha of rice land plus (in the dry season) 5.0 ha of horticulture, and in GMP3 91.4 ha of rice and 8.7 ha of horticulture : in all, 154.6 ha, so the canal's designed capacity is 3.34 l/s/ha based on the rice land, or 3.04 l/s/ha based on all land.

53 This canal was selected for study because it has reported water problems. These problems occur particularly in GMP3, which is the largest of the seven GMPs and which also has the largest incidence of certain other problems, including drainage and salinity problems as well as financial and social ones. The physical problems seem to be concentrated in the tail-end tertiaries, especially numbers 14 and 15.

54 Table 3 shows the findings of direct flow measurements made over one month, 23 September - 24 October 1992, on 3 pairs of tertiaries at the head, middle and tail of canal S2P1. These are based on direct measurements of discharge into each tertiary. To convert these to daily volumes of water delivered, it was assumed that the duration of flow on each day was the same as the pumping hours recorded at the main pumping station.

55 The data confirm that the head tertiaries received 125.0% of the average volume, whereas the tail tertiaries received 80.5%, so there seems to be head-to-tail inequity. However, even the deliveries received in the last tertiary seem to be 160% of potential evapotranspiration, so the matter may not be very serious.

56 Figure 10 shows the average yields observed on these 15 tertiary canals in the dry season of 1993. It does not seem clear that there is a strong head-to-tail effect. The final two tertiaries, 14 and 15, do indeed have low yields, but so does no. 6. If we temporarily ignore nos. 14 and 15, we find that the average reduction of yield from one tertiary to the next is only 1.1%. The inter-quartile ratio (ratio of best quarter to worst quarter) of these yields is 1.54, if tertiaries 14 and 15 are included; or 1.37 without nos. 14 and 15. None of these are bad figures, for this kind of data.

57 Should we say that the management of water in this canal is defective and needs to be changed? That is not very clear. A yield reduction of 1.1% per canal is not bad, and any alternative management arrangements might produce results that are no better than this. The specific problem of reduced yields along tertiary canals 14 and 15 may have various causes. Among the explanations that can be found at different places in the project reports are these :

a the people who farm land in GMP3 are socially distinct; they are mostly army veterans who did not have as much farming experience as the others;

b the upper tertiaries take too much water and not enough is left for the last tertiaries;

c there are patches of saline soil along tertiaries 14 and 15;

d the drainage facilities are insufficient and badly maintained, so there can be occasional waterlogging.

58 My impression is that we do not know the true cause. However the water supply explanation (ii) can easily be proved or disproved by a programme of visual monitoring of field wetness as discussed above in paragraph 38. If, in fact, we find that the fields on tertiary 15 remain wet, in spite of the lower input of water, then it would seem likely that bad drainage may be the explanation.

59 At present, therefore, it does not seem to be possible to say with certainty whether the present arrangements for distributing water among tertiary units are adequate or not. I recommend that adequacy and equity studies, based upon direct observations of field wetness, should be pursued, and should be extended to other GMP units as well.

COST AND PRODUCTIVITY OF WATER

60 The project team have made some interesting calculations about the cost of water, at Saga and at Kourani-Baria I. The cost of energy for pumping accounts for between 25% and 35% of the total cost of irrigation services that are provided to the farmers. However energy cost is only about half of the cost of water. When all costs related to the pumping station are included (amortisation and renewal of capital equipment, salaries of operators, and a proportion of ONAHA's general service charge to the co-operative) it appears that the total cost of providing water is 60-65% of the total irrigation cost.

61 Table 4 summarises the information available about water costs and crop output at Saga for the two seasons of 1992. It probably contains some errors and can be improved. However I think that it indicates the general situation quite well, and it suggests certain lines for further study. In making this Table 1 have have used crop yield data (line 10) from the ONAHA Annual Report for 1992 (reference 3). The other basic data (lines 1-4 and 8) come from the project's documents. the ONAHA dry season yield figure for 1992 seems rather low, but this does not greatly affect the following discussion.

62 The table shows that water applied in the wet season is quite productive, in an economic sense, but in the dry season the position is much less satisfactory. In the wet season the productivity of water was 0.81 Kg/m^3 (line 11), but in the dry season it was only 0.28 kg/m^3. Even if we consider that, in the wet season, there is a capacity to produce some paddy without irrigation, we can see that the marginal productivity due to adding irrigation water was 0.65 kg/m^3 (line 15).

63 These wet season figures are quite good, by current international standards, and they indicate an economic outcome that seems viable even if it is not especially good. The production value is 52.5 fCFA/m^3 (line 17) or 42.2 fCFA/m^3 if we consider the marginal product only. At 1992 exchange rates these figures were equivalent to about 19 or 15 US cents/m^3 which is probably better than the average current experience in developing countries.

64 The total cost of water charged to the farmer was 6.0 fCFA/kg paddy (line 12), or about 9.3% of the gross revenue obtainable from the crop. This is a rather high proportion of gross income, and normally we should hope to see it around 3-5%; however, we have to consider that this calculation of water costs includes capital and all other charges, and many countries would calculate only the recurrent costs as chargeable to farmers.

65 The wet season results look adequate, but the dry season ones do not. Especially, the product value of only 18.5 fCFA/m^3 seems much too low, and the charge to the farmers rises to 8.4 fCFA/kg, or 13.0% of gross revenue. These are not satisfactory levels, and they indicate an unsustainable situation.

66 There may be some doubts about the energy cost figures, which the project should verify in another season, because this question of water economics is highly relevant. The recorded energy cost in the dry season was 135% of the wet season cost, but the volume pumped was 235% of the wet season amount. Since the pumping head is more in the dry season, this seems unlikely, unless there was a change in energy price during the year. Any adjustments that may have to be made to these figures seem likely to increase the difference between the wet season and dry season economic performance.

67 The data so far available for Kourani-Baria I (reference 14) indicates that the water cost, in the wet season of 1992, was 2.49 fCFA/m^3, which is half of the wet season cost recorded for Saga, although the amount pumped was recorded as 12 642 m^3/ha. ONAHA recorded the mean yield in that season as 2 894 Kg/ha (reference 3). These figures differ very greatly from the Saga data, and again this confirms that more study of the question of water economics is necessary. According to the above data for Kourani-Baria I, the productivity of water was 0.23 kg/m^3, or 14.9 fCFA/m^3, and the water cost per kg of paddy produced was 10.9 fCFA/kg, or 16.7% of gross revenue. All of these seem to be very poor results.

CROPS AND FARM ECONOMICS

68 At present these three systems, Saga, Kourani-Baria I and Kourani-Baria II grow rice in both seasons. In the dry season the area of non-rice crops in Saga is 37.4 ha (reference 6). My understanding is that this is additional land, which is cultivated in the dry season only, and that there is little or no land where rice is grown in the wet season and other crops in the dry season.

69 The proportion of non-rice land is therefore about 9.8% of the rice land. However it seem to be considered important by the farmers, of whom 51% have some non-rice land (reference 11). The principal crops are tomatoes, cabbages, onions and other vegetables, and there is also a significant amount of fruit trees.

70 These horticultural crops seem to be a source of much revenue to the farmers. However they are not properly integrated into the irrigation operations. Water supply to them is "informal," which means that it is sometimes surplus water draining from the rice fields, and sometimes it is drawn by siphon pipes from the canals. People without horticultural crops complain about these practices. People with horticultural land do not have to pay irrigation charges for it.

71 The economics are not yet clear. These aspects are discussed, on the basis of a sample of 74 holdings, in reference 11, but the presentation is confusing at some points (for example, pages 35 and 39 give different figures for the ratio between revenues of horticultural and rice crops). However it seems clear that the revenue per hectare obtained from horticulture in the dry season is significantly better than that obtainable from rice.

72 I recommend that the project gives more attention to the outputs and economics of the horticultural crops. In view of the evidence given above, of the poor economics of dry-season rice, it seems clear that one possible policy alternative is to encourage crop diversification in the dry season, in order to enhance farmers' incomes. The project should therefore gather as much data as possible about the performance of these crops.

73 Collection of data on agronomy and farm economics is somewhat behind schedule. The initial activities in these areas in 1992 were very general. Starting in the wet season of 1993, a stronger programme of data collection has been established based upon monitoring a sample of 60 holdings in Saga. This is very welcome, and the information it is producing will be valuable. However

because of the relatively late start it needs to be accelerated. A similar programme of monitoring is to be started in Kourani-Baria I and Kourani-Baria II in the wet season of 1994, with over 100 holdings being monitored. There will be difficulties in managing the processing and reporting of these volumes of data.

74 The head of this work, Mr Chégou Maman, has requested some assistance on agricultural economics for IIMI headquarters. I recommend that Dr Samad should provide this. In order that such an input be fruitful, it would be desirable that it happen before the next dry season, so that whatever recommendations Dr Samad makes could be used in that season's monitoring, as well as in the wet season of 1995. If this task is assigned to Dr Samad, it should be understood that it would involve either one or two further visits during 1995, and a role in the interpretation and report-writing.

75 The data collected at Saga so far suggest that farm output is not correlated very closely with labour or with the level of expenditure on non-water inputs. There is no correlation at all between yield and household labour resources; no doubt this is partly because, at a peri-urban site such as Saga, hired labour is readily available.

76 Mean expenditure on non-water inputs was fCFA 9 200 per holding. It is weakly correlated with yield, suggesting that each additional fCFA 1,000 spent on inputs may increase output by about 140 kg/ha (35 kg/holding), giving a gross income benefit of about fCFA 2 300 to the holding. This seems plausible, but much more analysis, as well as more seasons' data, will be needed in order to understand the management implications of such data.

77 It is regrettable that the plot data cannot be associated with water data. We do not know whether one GMP gets better productivity of water than another. This is because water measurements are concentrated on GMP2 and GMP3, while the crop monitoring plots are distributed over the entire system. In Kourani-Baria I and Kourani-Baria II, I hope that compatible monitoring of

water and crops can be achieved together. Since water is the most expensive factor of production, it seems necessary to maximize our information about the effectiveness of its use. Therefore I would prefer a water-and-crop monitoring system which can inform us about all the GMPs in the system.

INSTITUTIONS AND FINANCE

78 The most difficult problem confronting these irrigation systems at the moment seems to be their financial sustainability. Figure 11 tells the basic story of the collapse of fee collections at Saga co-operative in the past five years, during which the annual collection ratio has fallen from 93% to 29%. Figure 12 shows that the collection is usually a little better in the wet season than the dry, but the difference is small.

79 This collapse is not the result of any attempt by the co-operative to increase the fees. As Figure 13 shows, the amounts demanded by the co-operative have been rather stable, and have indeed declined slightly in recent years at about 2.5% per year, perhaps in response to the non-payment.

80 This drastic reduction of cost recovery must threaten the sustainability of the system. For the time being, the co-operative keeps functioning, but it is accumulating large debts to the electricity suppliers and others. It has also, I understand, been able to gain access to the special account which is intended to be held for rehabilitation and renewals of capital equipment, and has made use of those funds to meet operational expenditures. I understand that the co-operative was re-financed at the time of the rehabilitation (1987) and it seems that it has been able to use funds provided then, rather than depend upon its collection from its own members. If these suggestions are true, they indicate a situation which cannot continue for more than a few years.

81 Many reasons are put forward to explain the collapse of the co-operative's income. Among them are these :

a Before 1988 authoritarian governments would be more ready to punish defaulters. The more democratic regimes of recent years are more lenient;

b Many members are dissatisfied with the co-operative, because it is not transparent and accountable, and is controlled by a traditional elite who are not sufficiently responsive to the ordinary members;

c Farmers' incomes are so low that they find it extremely difficult to pay; and the charges are set very high;

d Members think that the government or some external donor will, in the end, arrange funding and will not let the past investments become unproductive.

82 Each of these explanations could have some truth, but it is necessary that the project team reaches some conclusion as to which explanations are most likely to be correct. Policy recommendations by the project will depend on this.

83 Some of the explanations could be tested by the project. For example, if other systems in the country all show similar patterns of fee collapse, as in figure 11, then it is not necessary to seek specific explanations for Saga, like item (b). If explanation (c) is true, then we should expect that recoveries in 1994 will improve, because the currency devaluation has improved gross revenue.

84 I believe it is quite likely that explanation (d) will turn out to be the most appropriate one. It is one of the commonest problems of any privatization programme : the question of credibility. {In this sense it is almost the same as explanation (a)}. The problem may be that people do not see any good reason

to pay. If there are no benefits for payers, and no penalties for non-payers, then it is difficult to see what will make the situation improve. We cannot say that the irrigation service is itself a benefit for fee payers, because it seems that people have now discovered that non-payers also obtain that benefit.

85 The project team have made various comments about the fact that the Saga co-operative contains many influential people, some of whom are on the committee, and that discontent with these people is one of the major problems. They (in many cases) fail to pay; but are sufficiently influential so that no action is taken against them; then others follow this example. I do not yet feel quite convinced of this. It may be true; but if it is, then we should expect to find that (for example) Kourani-Baria II has a much better fee collection and social cohesion.

86 The question of farmers' capacity to pay is a fundamental one. Viability of the co-operatives is impossible if farmers genuinely cannot pay the charges. As noted earlier, the charges for water alone are a high proportion of farmers' revenue, especially in the dry season. Figure 13 shows that the total irrigation charge has been in the region of fCFA 110,000 per hectare per year. In international terms, this is about US$ 400 per hectare. It is extremely high, by the standards of other developing countries.

87 The payments actually made are much less, as Figures 11 and 12 show. Figure 14 shows the recorded fee collection at Saga in terms of fCFA per kg of paddy produced. By 1992 it had fallen to fCFA 3.27, or about 5% of gross income. This seems to be a more realistic level of capacity than the 17.5% which the co-operative tries to collect.

88 The institutional system involves three principal entities : the GMP, the co-operative, and ONAHA. The project has not yet given much attention to the GMP level. Asian experience suggests that this level is potentially very significant, and benefits might come from strengthening it. A co-operative with over a thousand members, as at Saga or Kourani-Baria I, faces considerable difficulties in making its members feel a sense of involvement; a local-level unit

like the GMP is normally necessary because it can develop more cohesion and commitment. This level of organization is also normally appropriate for arranging water distribution and many other practical functions.

89 I think that the team should give more attention to comparing the performance of the different GMP units in order to see whether they differ in important ways. It would be useful to find out what are the characteristics of a successful GMP. For example, I understand that half of the arrears of fee payment in Saga co-operative arise in GMP3. The yield of rice in GMP3 does not seem to be less than the average, so capacity to pay is similar. Why are they less willing to pay? It is possible that it is affected by the fact that this GMP, with over 400 holdings, is too large to have the social advantages of a local organization, and that matters would improve if it were split into 2 or 3 units. Matters like this could be explored by developing some systematic comparative studies.

90 The Saga co-operative has an Audit Committee of 3 members with accounting skills, whose function is, in theory, to supervise the financial management of the co-operative (reference 6). However its members seem to have been discouraged from effectively fulfilling this task. It will be useful to compare how the other co-operatives can perform this function. It is important to establish whether this kind of behaviour is a special characteristic of Saga, or is a normal feature of these co-operatives.

91 A similar comment would apply to the question of election processes for GMP and co-operative committees. The project team members have expressed dissatisfaction with the quality of these procedures at Saga, where the same people are in office for many years without changes. It is necessary to discover whether this happens everywhere, or is peculiar to Saga.

92 In general there seem to be many indications that farmers are not adequately motivated to support the co-operative and become involved in its affairs. Arrears of payments of fees are one sign; failure to perform group tasks like clearing of drains is another sign.

93 I think that the project team should give special thought to the problem of how to develop positive attitudes towards the co-operative. Every member should be able to see some personal advantage in membership and participation. This might be obtained if the co-operative could (for example) be a channel for cheaper credit and inputs, or for effective marketing. At present, I understand that only about 10% of the rice crop at Saga is marketed through the co-operative. That suggests that the farmers do not generally perceive it as a useful organisation for them.

94 In regard to group labour on activities like drain clearance, it is certain that this will be difficult or impossible to organise unless there is some credit given to those who participate. Any contributions of labour by individual farmers or their family members, towards group activities, should be recorded at the GMP level, and fees due from such farmers should be accordingly reduced.

95 It may be useful for the team to study the eight "design principles of long-enduring, self-organised irrigation systems" that have been identified by Elinor Ostrom after extensive analysis of many such system. These are reproduced here in Appendix D. The Nigérien co-operatives, at present, do not satisfy all these principles.

SOCIOLOGY AND LAND TENURE

96 I am not in a position to comment in much detail about the sociological data collected at Saga, because there was no opportunity to study it closely during this visit, apart from reference (11). This area seems to me unclear as yet. References (8) and (9) contain recommendations about the structure of sociological questionnaires, which will produce detailed descriptions of the communities. The data will certainly be very interesting, but it may be difficult to see how to develop recommendations for changing the present situation.

97 The problem is that, almost certainly, the project must propose some changes to the existing institutional system, because the present failure of fee collection is likely to make the existing system unsustainable. It is difficult to propose changes just on the basis of descriptions of the present system, because we do not know what the consequence of any changes will be. Probably the best way to approach this difficulty is by means of comparative studies. If the team can identify GMPs or co-operatives which have higher or lower performance than average in such aspects as fee collection, or high production, or low water consumption, then these units can be intensively studied in order to find out why they perform better. Out of such an analysis, improvement recommendations can be developed more confidently.

98 This means that sociological data collection should, if possible, be focussed most closely upon those units with outstandingly low or high performance.

99 The role of land tenure should be studied, in relation to performance indicators like water consumption, crop output and fee payment. A process seems to be going on by which about half of the Saga farmers have acquired more than one holding. Is this desirable? Would performance improve or deteriorate if more farmers can operate multiple holdings? Does the family size, or number of active members per hectare, have any relationship with the principal performance indicators? It should be possible for the sociological component to address these performance-based questions.

100 More generally, I think that the questionnaires in the sociological component could be focussed more sharply, if the team can identify specific performance issues that need to be addressed. We need to relate sociological factors to irrigation performance indicators, so that we can estimate what will be the effect of introducing any sociological adjustments.

RECOMMENDATIONS

101 The following is a summary of my recommendations for the future conduct of these studies.

a The critical question facing these systems at present seems to be the financial sustainability of their managing organisations, the co-operative. To solve this, the team will have to devise recommendations for reducing the costs of operating the systems, and for increasing the level of fee payment by the farmers.

b Water, and especially the cost of pumping it from the river, is the biggest element of cost. At present, the ratio between the value of crop output and the cost of irrigation water is much worse in the dry season than in the wet. Special attention therefore has to be given to reduction of water use, and to enhancement of crop value, in the dry season (paragraph 62-67).

c The project should therefore give higher attention to the outputs and the economics of the horticultural crops, in the dry season (paragraph 72).

d The project should develop more comparative studies, aimed at comparing the performance of different GMP units and different co-operatives, in order to identify characteristics of successful organisations (paragraphs 89, 96).

e Monitoring of water and crops should be done on a compatible basis (paragraph 77) and should be linked to the institutional system, so that it is possible to know which GMPs use water most effectively.

f The process by which GMP representatives estimate their water needs and communicate these to the pump operators should be examined in detail (paragraph 46). Methods of improving it should then be sought; but in principle a process of communicating needs from farm level up to system level is good, and is likely to be more efficient than any imposed rotation system that would be controlled centrally by the co-operative and the pump operator.

g Adequacy and equity of water supplies, in a rice-based system, can be estimated by observing daily how many fields do or do not have water standing in them (paragraphs 38, 59). Such observations of field wetness are easy to organise and more meaningful than studies of water discharge rates in the supply channels.

APPENDIX A

Terms of reference for the visit

1 Review and comment on data and reports of PMI-N on the three research sites.

2 Use existing information from PMI-N work and other sources to determine the representativeness of the project research sites to problems faced by river-based irrigation systems in Niger in particular, and by the Nigérien irrigation sector in general. (This may require supplementary site visits.)

3 Make recommendations to help better attain project objectives within the time remaining for the project.

4 Make recommendations with respect to eventual creation of a second phase of the PMI-N project.

5 Provide observations/recommendations on other potential collaborative activities (World Bank Small-scale irrigation; ICRAF windbreaks; WARDA-IIMI irrigation management training; etc.)

6 Provide recommendations and assistance as necessary to help put together an eventual paper for IIMI's Internal Program Review, on the work on PMI-N (choice of theme, presentation, write-up, etc.)

7 Review the potential for developing additional core-assisted projects (CAPs) similar to the gender project, in collaboration with IIMI-headquarters.

8 Review the proposal of André Guillerminet to simulate system operation to improve performance and to conduct irrigation trials to determine water use efficiency.

9 Provide other inputs as required.

APPENDIX B

DOCUMENTS AND REPORTS EXAMINED DURING THE VISIT

1 BANQUE AFRICAINE DU DEVELOPPEMENT : Projet d'appui institutionnel au Ministère de l'Agriculture et de l'Elevage pour la recherche - développement en management de l'irrigation. 31 October 1990. [AFRICAN DEVELOPMENT BANK : Project for the provision of institutional support to the Ministry of Agriculture and Livestock for research and development in irrigation management]

2 ONAHA (Office national des aménagements hydro-agricoles : National Office for Irrigation Systems) : Rapport annuel, année 1989-90. March 1991.

3 ONAHA : Rapport annuel d'activités, 1992. March 1993.

4 PMI-NIGER : Diagnostic rapide du périmètre rizicole de Saga : 17-21 juin 1992

5 PMI-NIGER : Diagnostic rapide du périmètre rizicole de Kourani Baria : 14-23 juillet 1992.

*6 CHEGOU MAMAN : Diagnostic approfondi du périmètre rizicole de Saga : Résultats préliminaires. IIMI-INRAN (Institut national de la recherche agronomique du Niger : National Institute of Agronomic Research of Niger). December 1993.

*7 PMI-NIGER : Diagnostic approfondi du périmètre de Saga : volet hydraulique. Juin 1994.

8 ANONYMOUS : Compte rendu de la mission d'appui sociologique du 11 juillet au 23 juillet 1993. PMI-Niger.

9 ANONYMOUS : Compte rendu de la mission d'appui sociologique du 2 au 11 février 1994.

*10 MME ASSAHABA : Présentation du périmètre de Saga. Juin 1994.

11 SOPHIE LE VU : Contribution au diagnostic social du périmètre de Saga. BPDA-SCETAGRI, Paris. May 1994.

*12 CHEGOU MAMAN : Saga : Données SH 93

13 ISSOUFOU ZAKARI : Analyse de l'itinéraire technique et des paramètres agrologiques sur le périmètre rizicole de Saga. Université Abdou Moumoumi, Niamey.

*14 PMI-NIGER (Abdou Ahmed Moulaye, Rabiou Almadjir, Laouali Mamane) : Rapport du diagnostic approfondi de Kourani Baria I et II. 13 juin 1994. (Provisoire.)

15 CHEGOU MAMAN : Programmes de recherche en systèmes de production, campagne 1994. PMI-Niger, avril 1994.

16 GUÉRO YADJI : Rapport périmètre de Tillakaina : quelques éléments sur les techniques culturales (campagne SS 92). ONAHA/PMI-Niger.

17 ABDOU MOSSI : Rapport de stage : le manioc, les arbres fruitiers, et les sols sur le périmètre de Tillakaina (période juillet - septembre 1992). ONAHA/PMI-Niger.

18 DADI BARMOU FATIMA MASSALATCHI (ed.) : Proceedings du séminaire sur "Relations genre et le management de l'irrigation," Niamey 6 janvier 1994. IIMI/PMI-Niger.

19 ISSIFOU SEYNI : Caractérisation du bassin versant de Sébéri. Dissertation, Faculté d'Agronomie, Université Abdou Moumouni, Niamey. 1994.

20 M DINGKUHN AND K A LONSWAY : Development of ecologically-sustainable irrigation-based land use strategies for the Sahel : joint studies in Senegal and Mali. 10 June 1994.

21 P N WINDMEIJER AND W ANDRIESSE : Inland valleys in West Africa : an agro-ecological characterization of rice-growing environments. ILRI, Wageningen, Netherlands. Pub. 52. 1994.

* Items marked thus are drafts or preliminary versions.

APPENDIX C

IRRIGATION SYSTEMS IN NIGER

TILLABERI REGION : LEFT BANK

	ha	Date of establishment
Firgoune	182	1983
Diomana	424	1991
Gabou-Bonfeba	324	1991
Namari-Goungou	729	1980
Djamballa	661	1983
Tillakeina	86	1967
Toula	256	1975
Daikaina	120	1964
Daibéri	350	1986
Kokomani	54	1974
Sona Cuvette	162	1974
Sona Terrasse	39	1977
Lossa	173	1974

TILLABERI REGION : RIGHT BANK

Yelewani	120	1984
Kourani-Baria I	425	1986
Kourani-Baria II	268	1989

NIAMEY REGION : LEFT BANK

Koutoukale	341	1981
Karma	133	1971
Goudel	51	1989
Saga	395	1966
Liboré	272	1973
Ndounga I	286	1974
Ndounga II	285	1975
Sébéri	397	1979

NIAMEY REGION : RIGHT BANK

Lata	242	1990
Namardé	245	1984
Karaigorou	144	1970
Kirkissoye	100	1970
Saadia Amont	111	1973
Saadia Aval	26	1985
Tiaguirire	183	1984
Say I	250	1981
Say II	195	1988

GAYA REGION : LEFT BANK

Boumba	22	1990
Gaya Amount	170	1990

GAYA REGION : RIGHT BANK

Tara	120	1975

KONNI REGION

Konni 1 + 2	2 447	1979
Ibohamane	750	1969
Galmi	250	1984
Moulela	65	1965
Kawara	52	1968
Tounfafi	28	1968
Djiratawa	512	1981

DIFFA REGION

CDA/Diffa	160	
Lada	60	1981
Tam	20	1979

APPENDIX D

DESIGN PRINCIPLES OF LONG-ENDURING, SELF-ORGANISED IRRIGATION SYSTEMS

Professor Elinor Ostrom, in "Crafting institutions for self-governing irrigation systems," identified eight design principles for sustainable organisations of this type. These rules, which are derived from analysis of the success or failure of many such systems, are :

1 Clearly defined boundaries

Both the boundaries of the service area and the individuals or households with rights to use water from an irrigation system are clearly defined.

2 Proportional equivalence between benefits and costs

Rules specifying the amount of water that an irrigator is allocated are related to local conditions and to rules requiring labour, materials and/or money input.

3 Collective-choice arrangements

Most individuals affected by operational rules are included in the group that can modify these rules.

4 Monitoring

Monitors, who actively audit physical conditions and irrigator behaviour, are accountable to the users and/or are the users themselves.

5 Graduated sanctions

Users who violate operational rules are likely to receive graduated sanctions (depending on the seriousness and context of the offence) from other users, from officials accountable to these users, or both.

6 Conflict resolution mechanisms

Users and their officials have rapid access to low-cost local arenas to resolve conflict between users or between users and officials.

7 Minimal recognition of rights to organise

The rights of users to devise their own institutions are not challenged by external government authorities

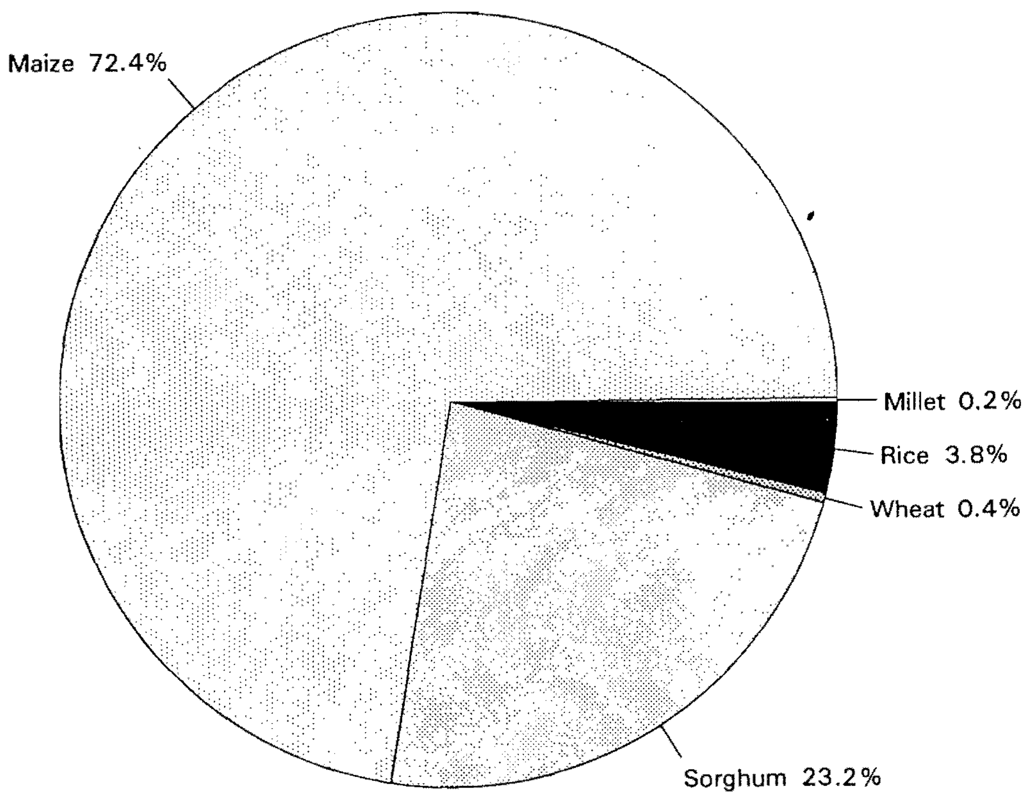
8 Nested enterprises

Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organised in multiple layers of nested enterprises.

The irrigation co-operatives existing at present in Niger do not seem to follow principles 2,3,5,6 and 8.

FIGURE 1

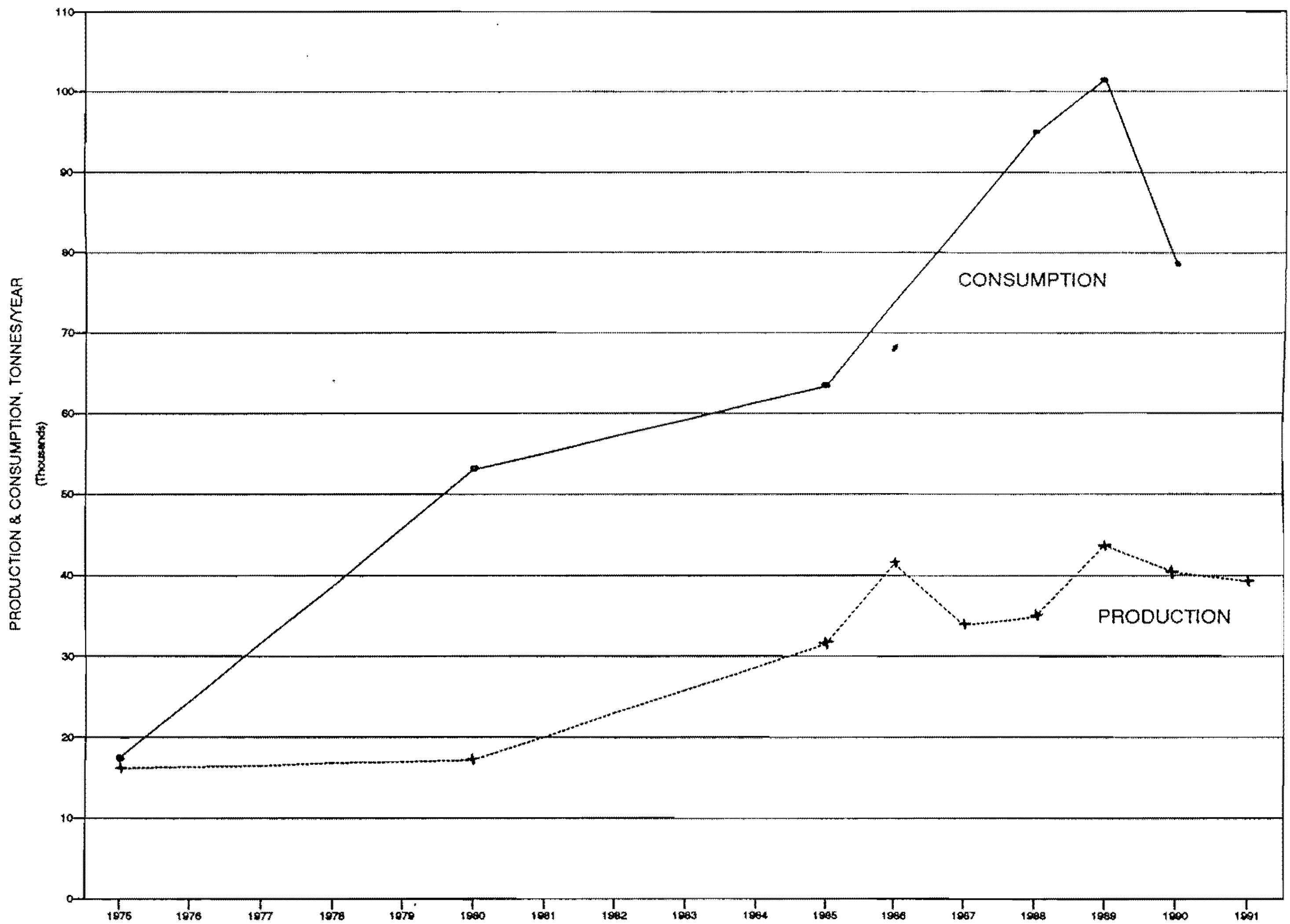
OUTPUT OF CEREALS IN NIGER, 1987-91



Source: FAO Production Yearbooks

FIGURE 2

PRODUCTION AND CONSUMPTION OF RICE IN NIGER, 1975-91



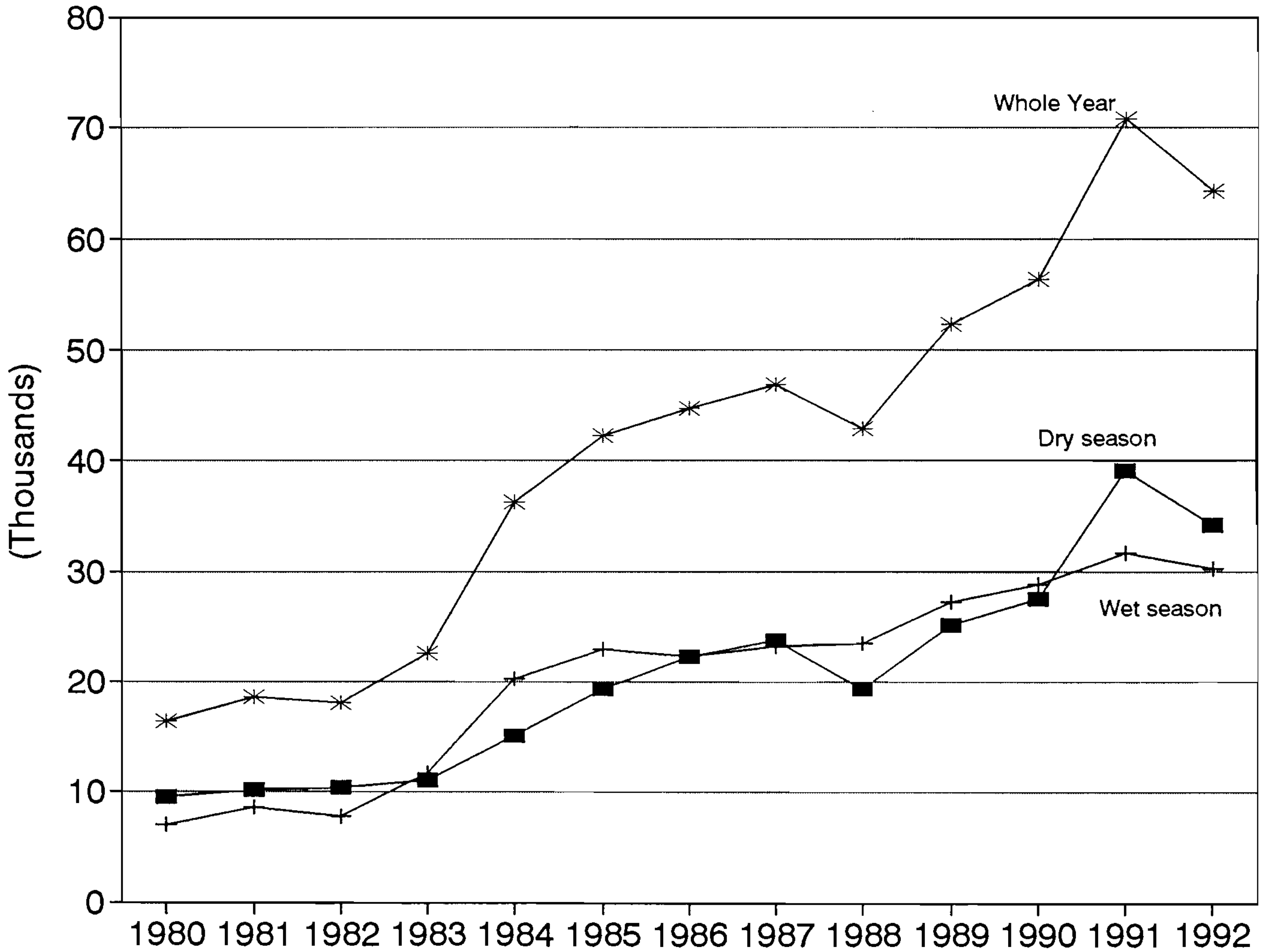
Sources : References (21) and FAO Production Yearbooks

Notes : 1 Production data are after deductions of allowances for post-harvest losses and retentions for seed
2 1 tonne of paddy is assumed to provide 650 Kg of milled rice

FIGURE 3 :

PRODUCTION HISTORY OF RIVER RICE-IRRIGATION SYSTEMS IN NIGER

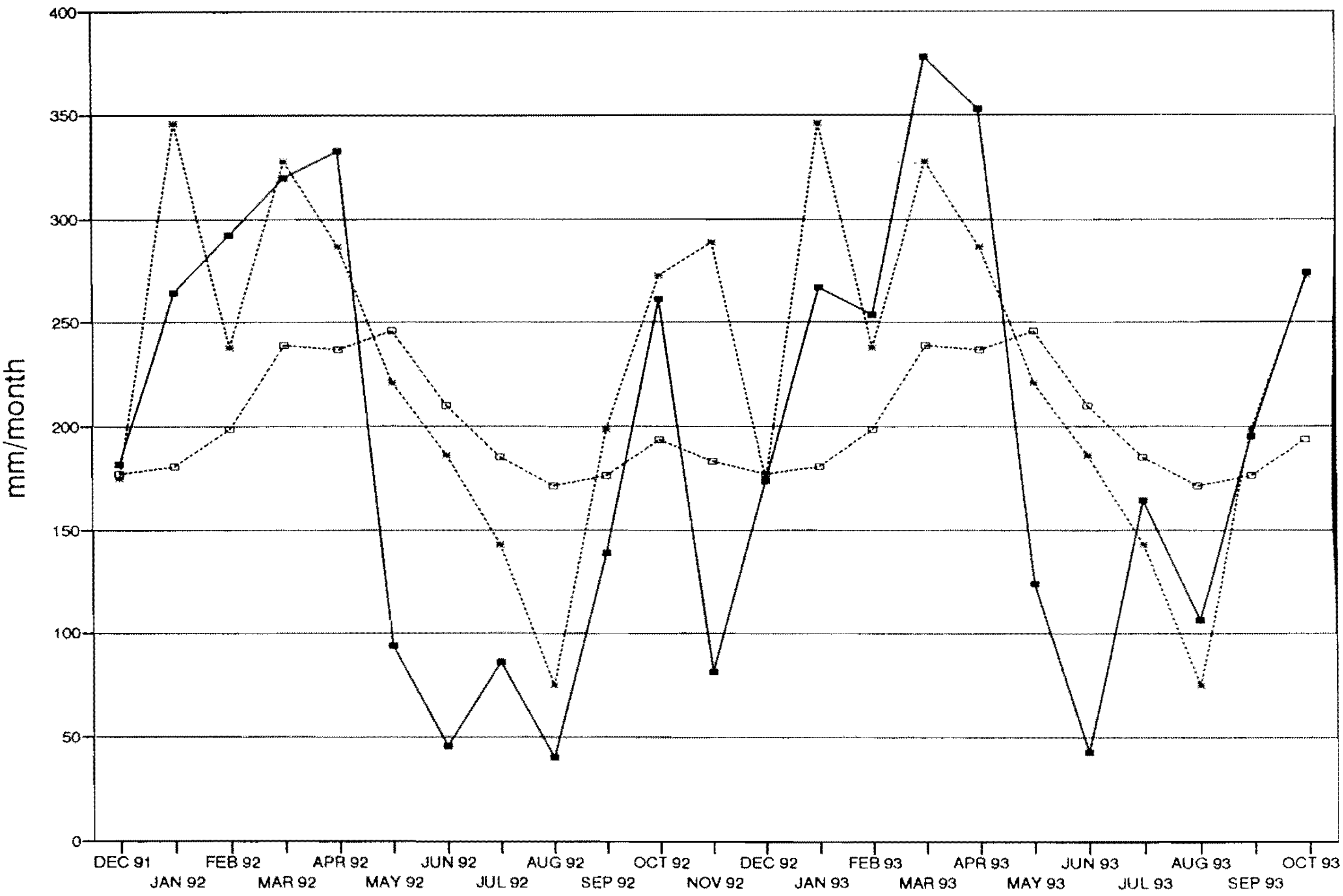
Units : tonnes of paddy



Source : ONAHA, reference (3)

FIGURE 4

WATER REQUIREMENTS AND WATER SUPPLIES AT SAGA, DEC 1991 - OCT 1993



———	Equivalent mean depth pumped
....	Mean evapotranspiration
---------	Estimate of total requirements

Note: Evapotranspiration and Total requirements are averages based on several years' data. Mean depth pumped is based on actual measurements for the current year.

FIGURE 5

Relationship between water pumped and crop water requirement at Saga

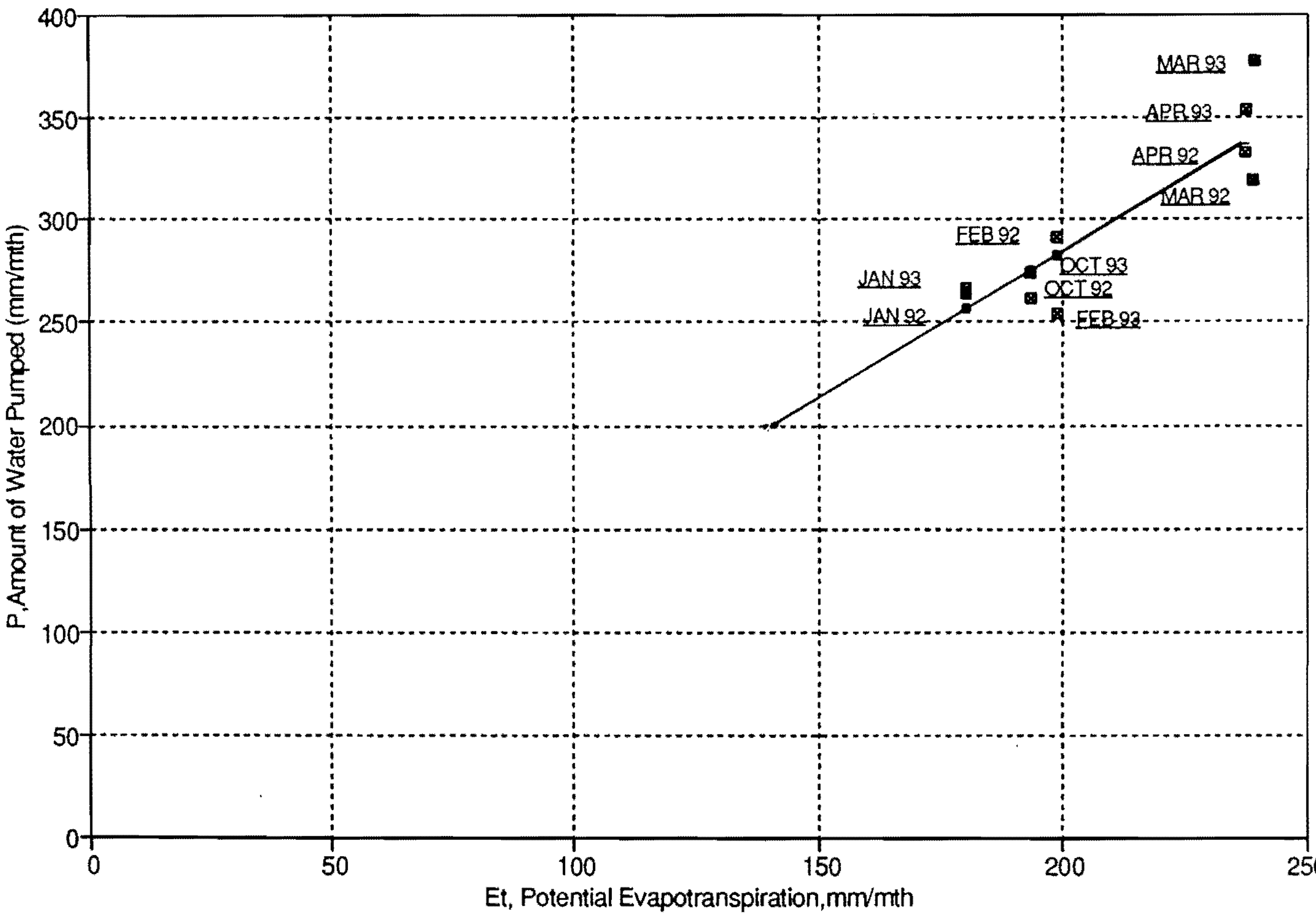
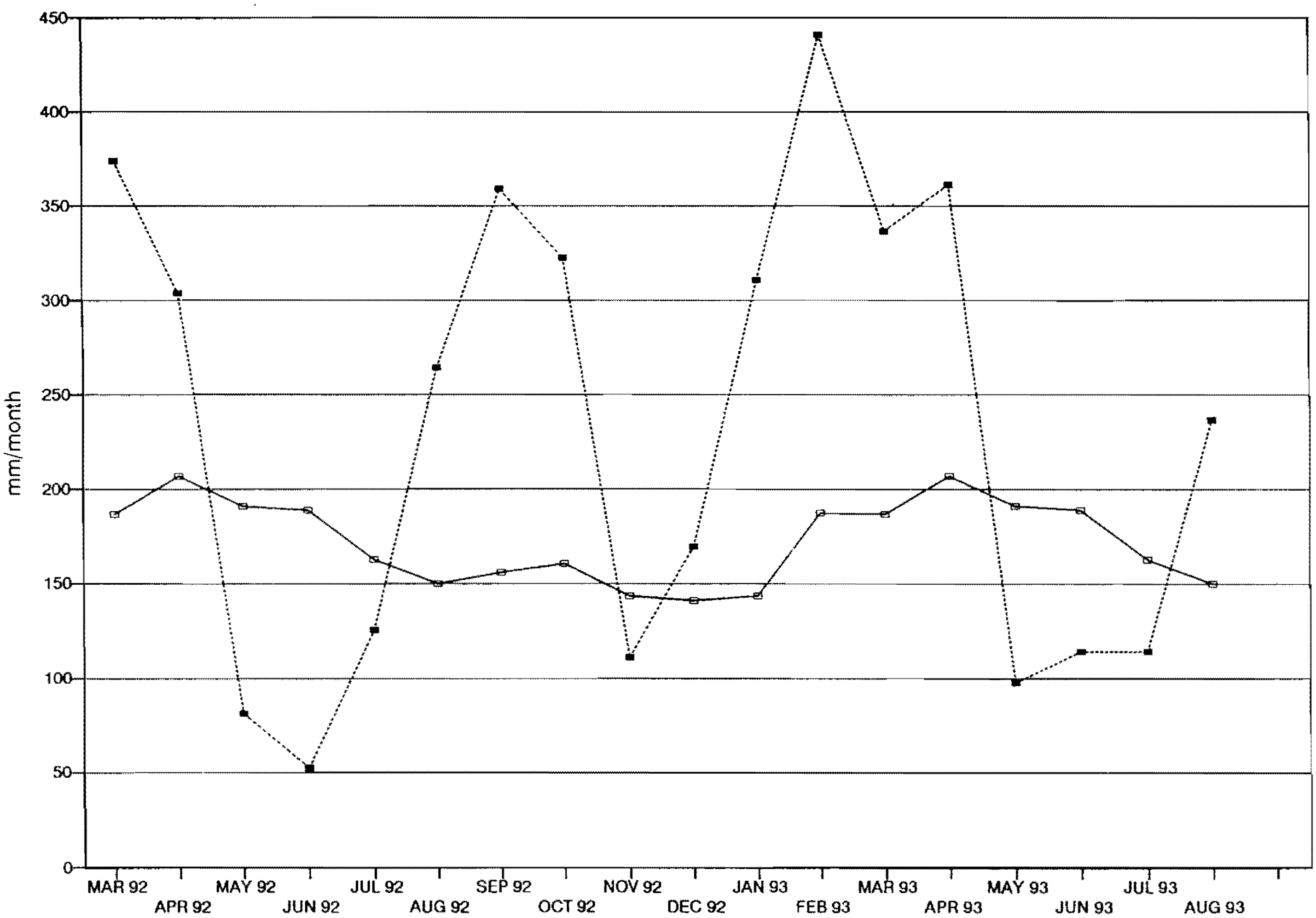


FIGURE 6

MONTHLY EVAPOTRANSPIRATION AND WATER DELIVERIES AT KOURANI-BARIA I, MARCH 1992 - AUGUST 1993



Equivalent mean depth of water pumped
Mean monthly evapotranspiration

Note: 1 Evapotranspiration rates are averages observed at Tillabéry over several years
2 Water deliveries are actual observed pumping rates

FIGURE 7

LOCATION OF GMP UNITS IN SAGA

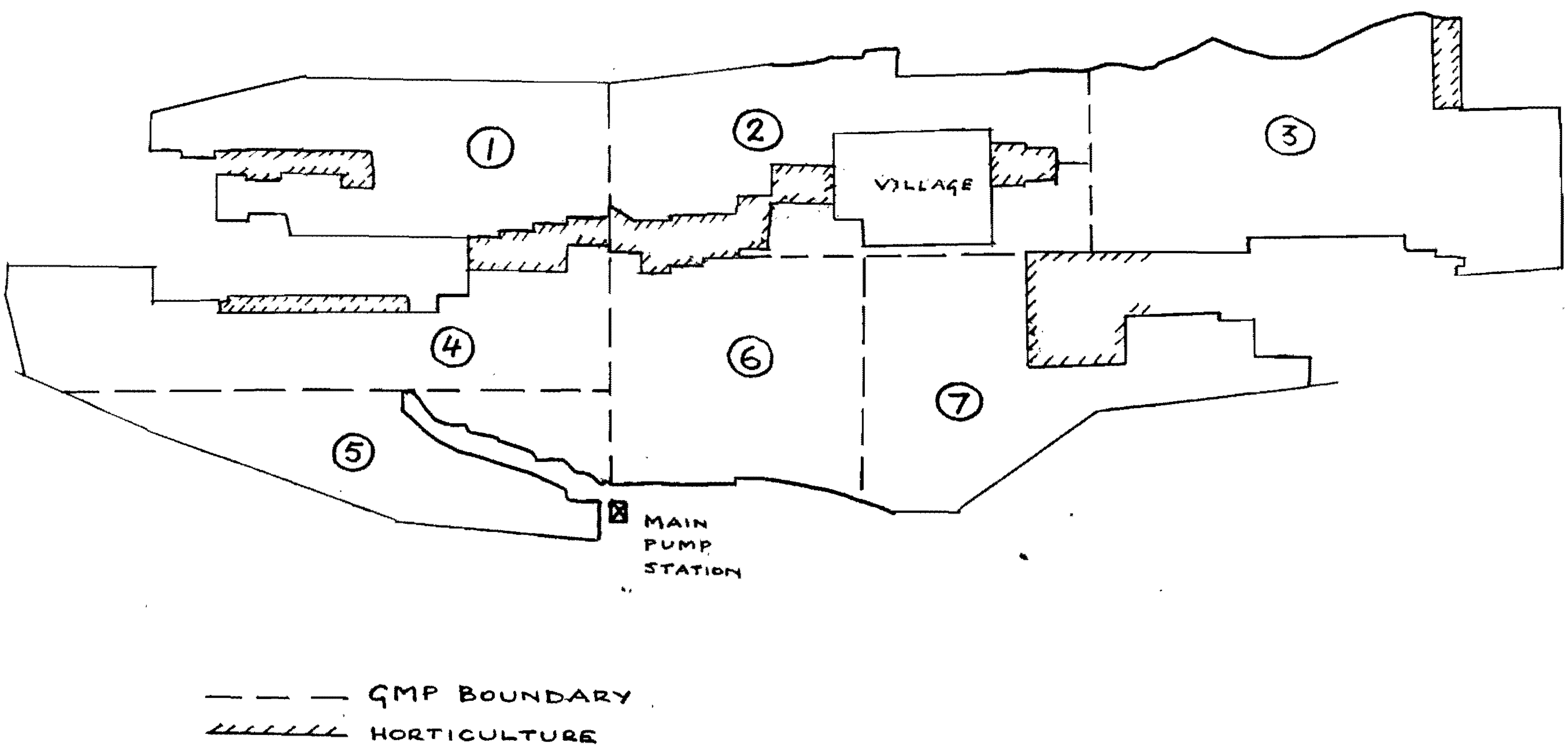
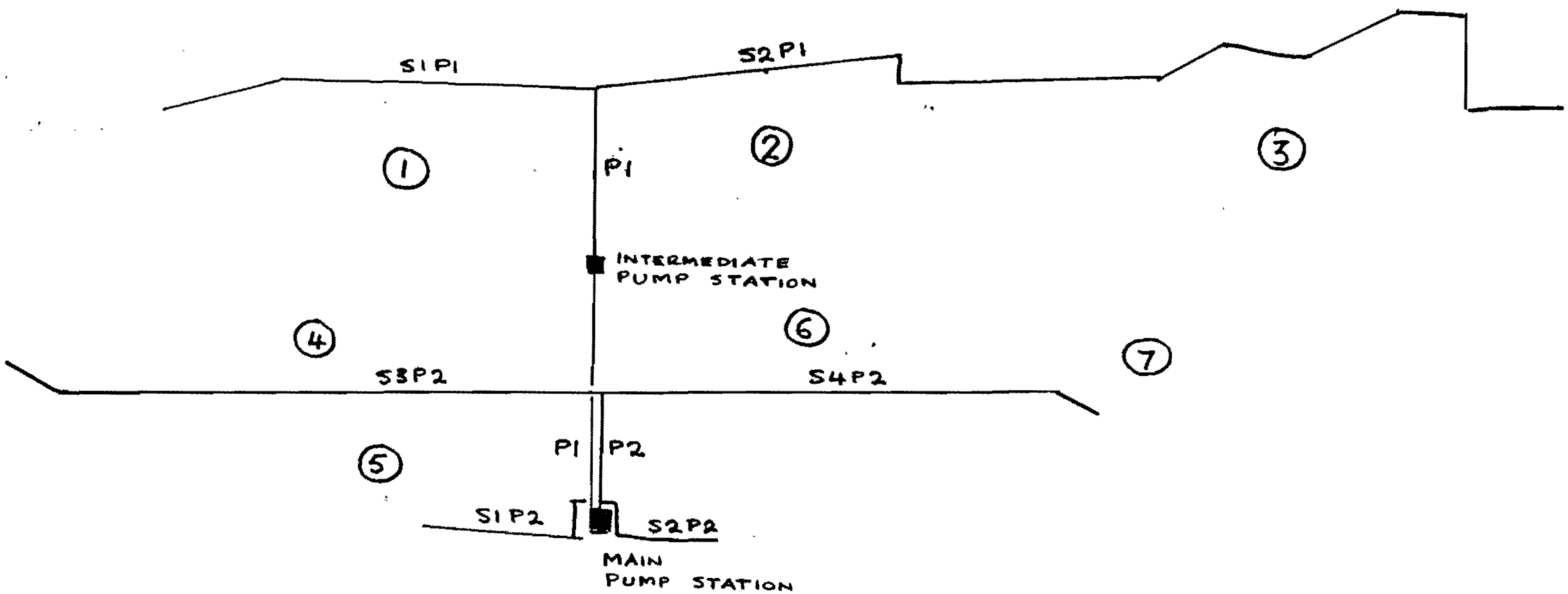


FIGURE 8

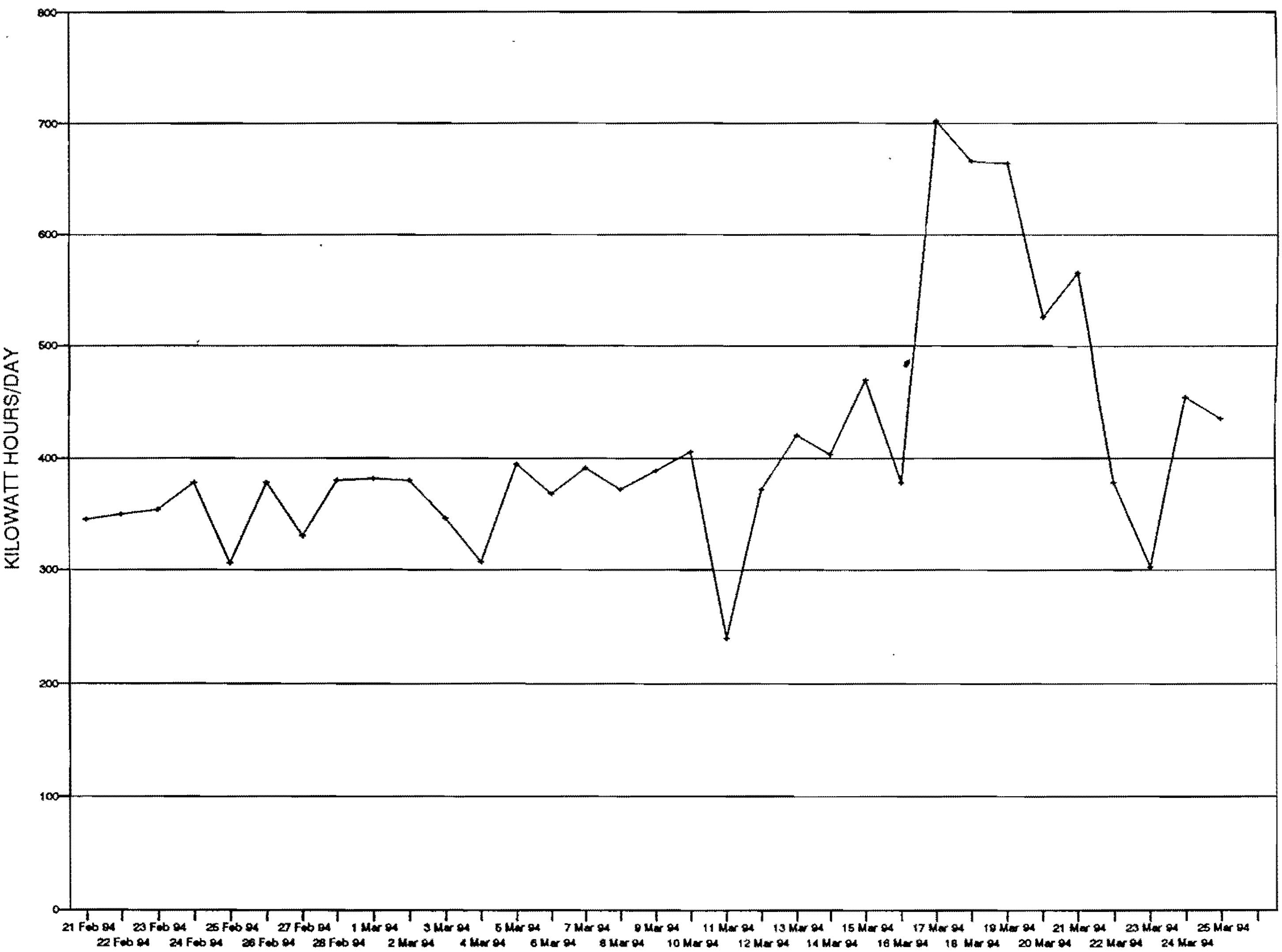
LAYOUT OF PRIMARY AND SECONDARY CANALS AT SAGA



(N) : LOCATION OF GMP N

FIGURE 9

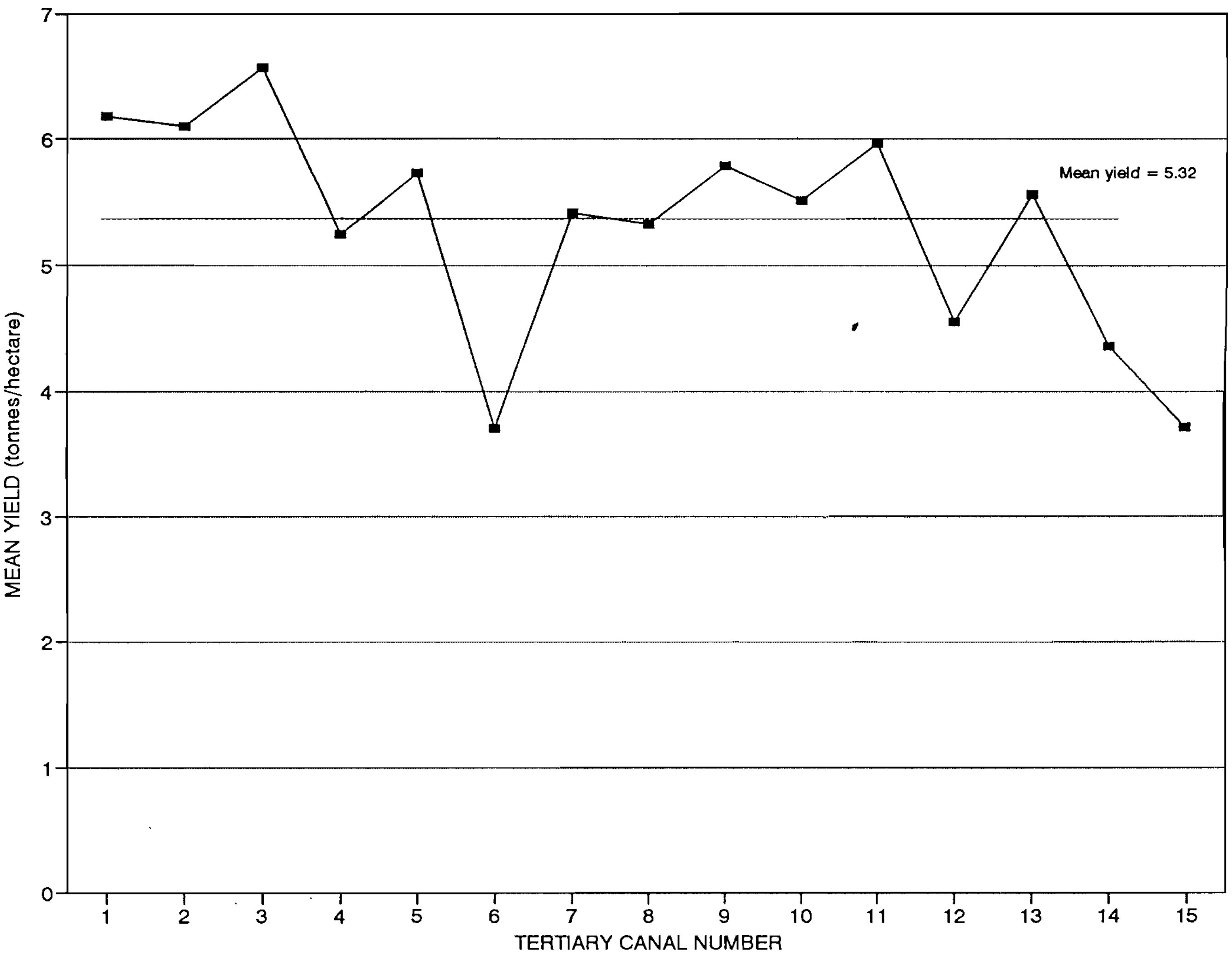
ENERGY USED AT MAIN PUMPED STATION, SAGA
21 FEBRUARY - 25 MARCH 1994



Source : Pump station log books

FIGURE 10

YIELDS OBSERVED ALONG TERTIARY CANALS OFF SAGA SECONDARY CANAL S2P1 : DRY SEASON 1992

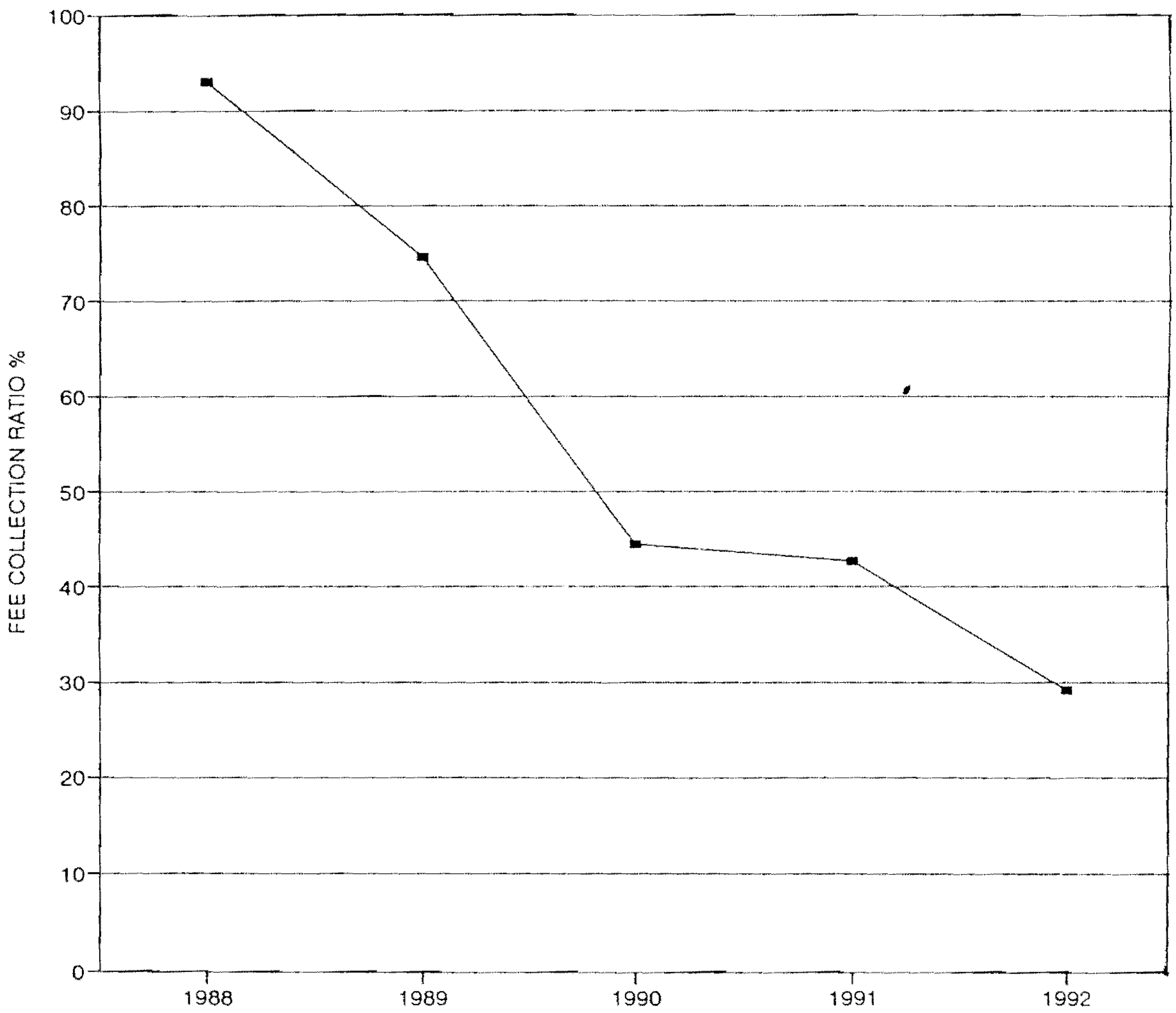


Source : Reference (7), page 91

Note : Tertiary canal no. 1 is at upstream end of S2P1, and tertiary canal no. 15 is at all

FIGURE 11

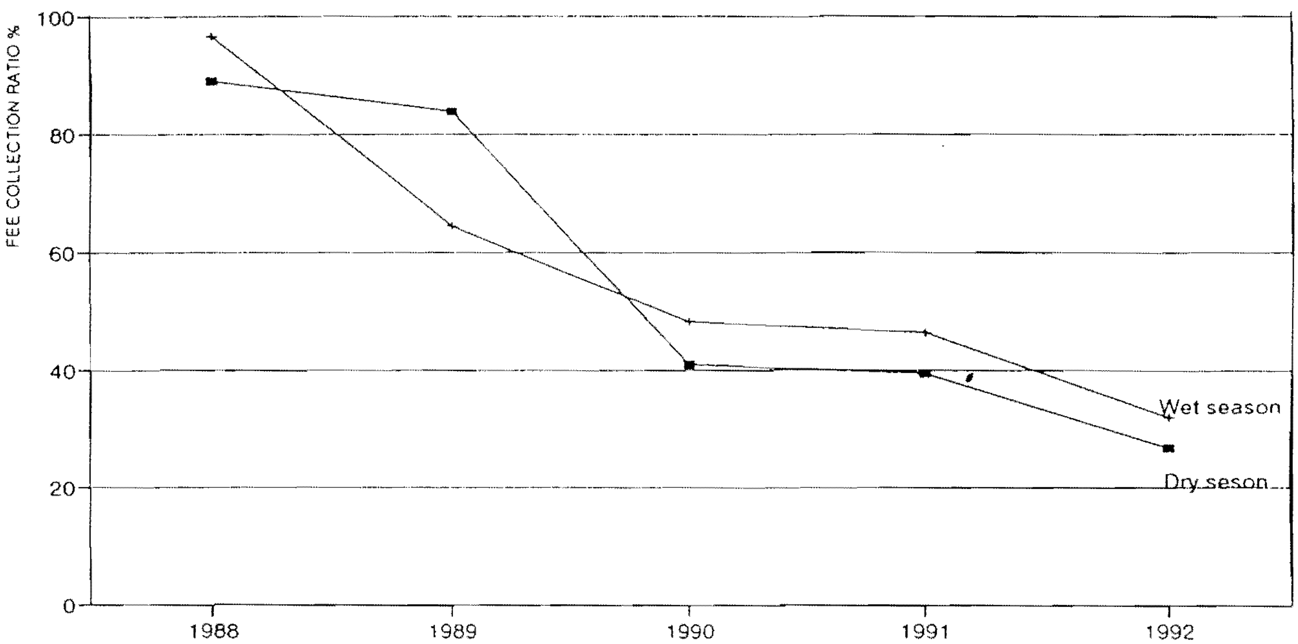
ANNUAL FEE COLLECTION RATIO AT SAGA, 1988-92



Source Reference (6) page 72

FIGURE 12

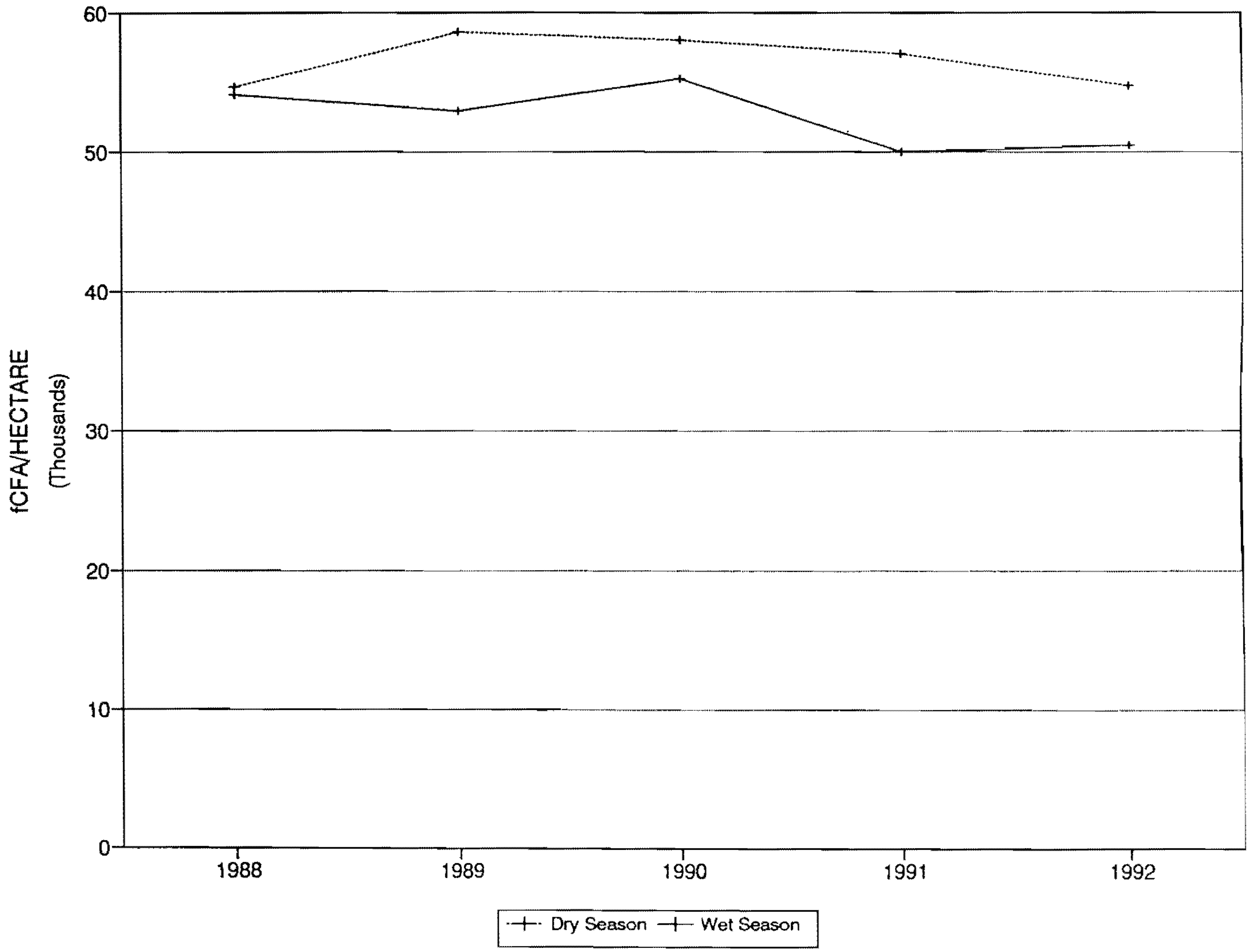
SEASONAL FEE COLLECTION RATIOS AT SAGA, 1988-92



Source Reference (6) page 72

FIGURE 13

FEES CHARGED BY SAGA CO-OPERATIVE, 1988-92



Source: Reference 6

FIGURE 14

FEES COLLECTED PER KG. OF PADDY PRODUCED,
SAGA, 1988-92

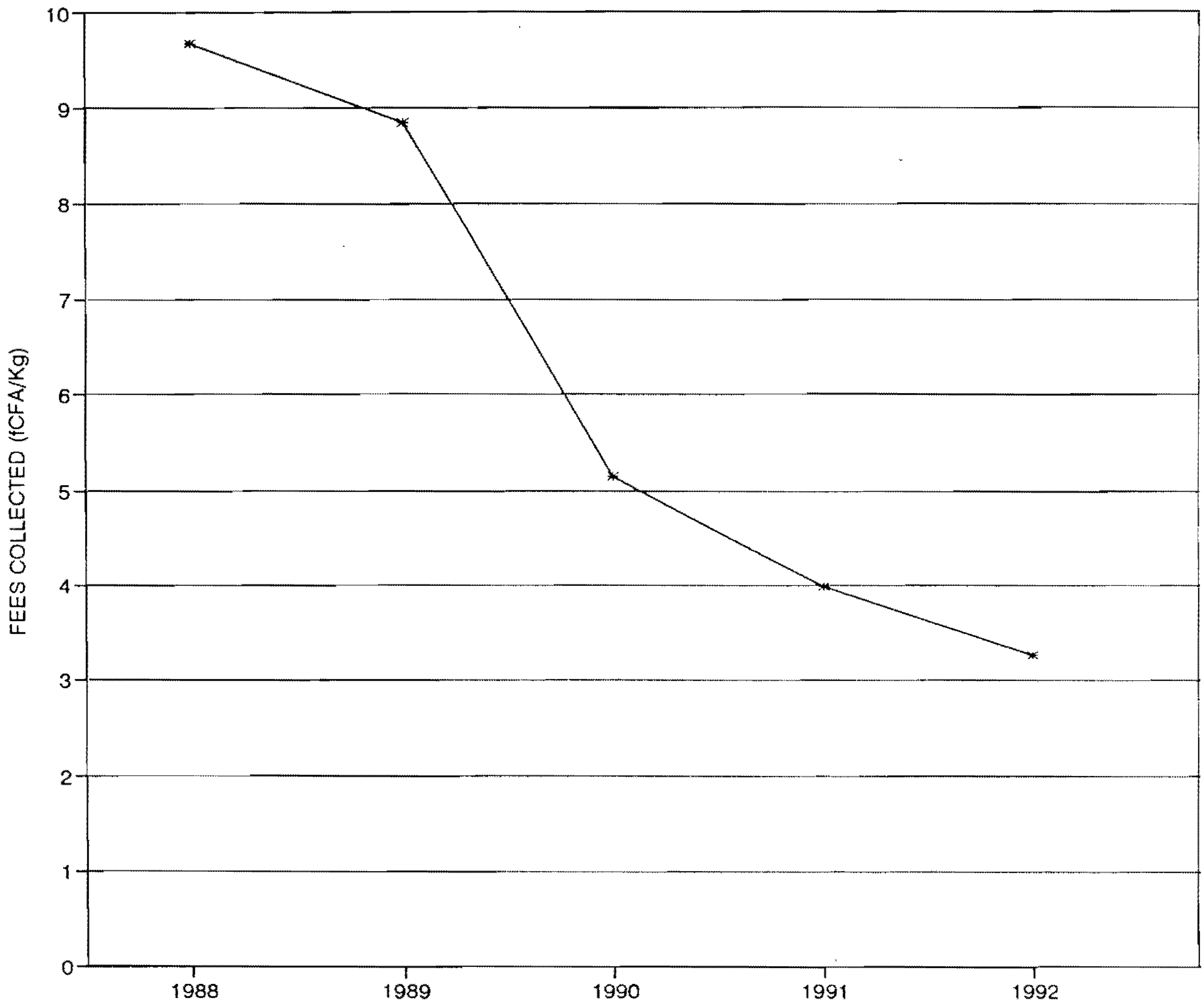
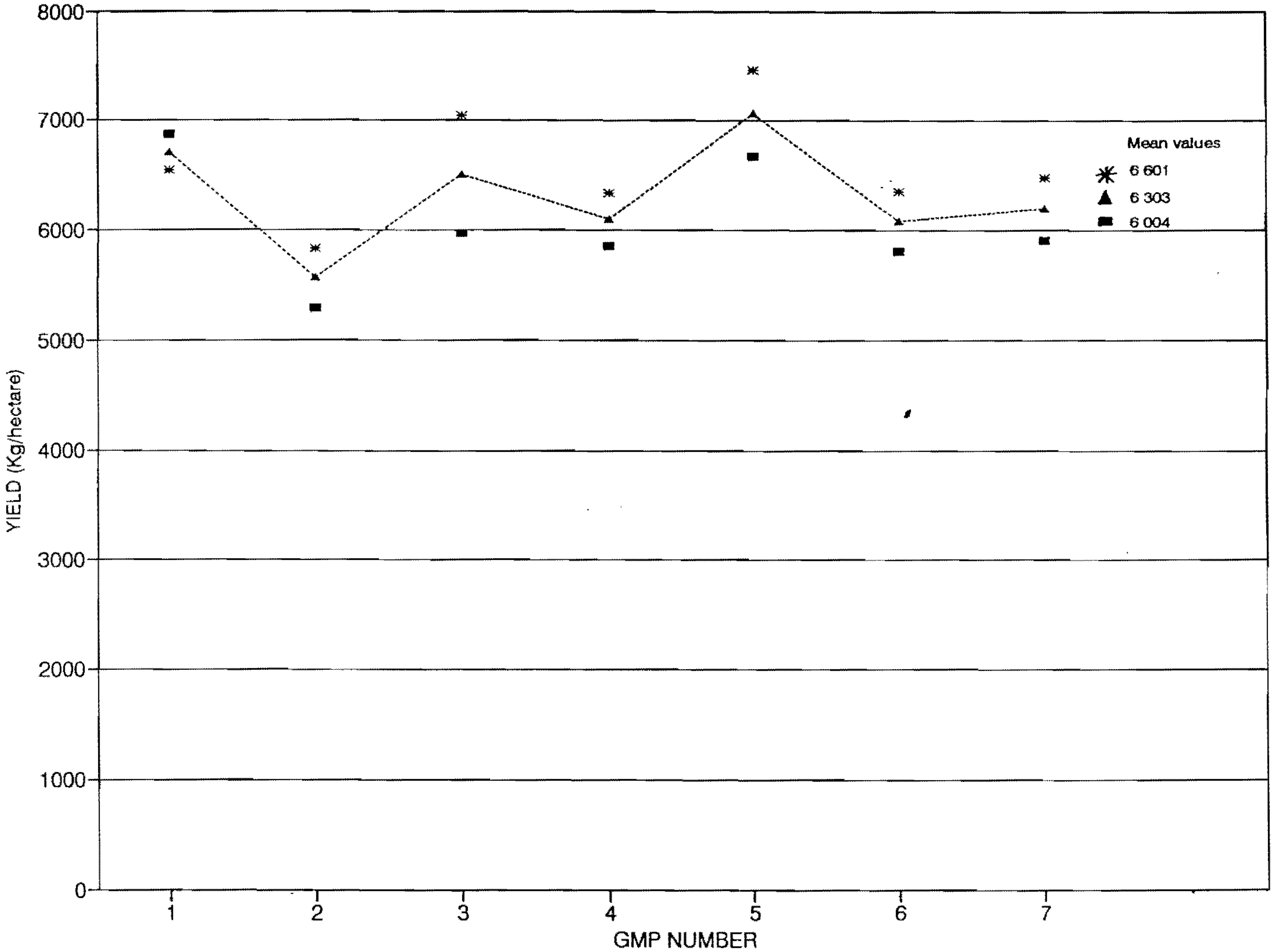


FIGURE 15

PADDY YIELDS IN EACH GMP AT SAGA : WET SEASON 1993



Measurement by crop cut
Farmers' own information
Average of these

Source: Reference 6

TABLE 1: WATER REQUIREMENTS AND WATER SUPPLIES AT SAGA, DECEMBER 1991 - OCTOBER 1993

Month	Volume of Water pumped (m^3/month)	Equivalent mean depth of water pumped (mm/month)	Mean monthly evapotranspiration (mm/month)	Project's estimates of total requirements (mm/month)
DEC 91	682 964	182.1	176.8	174.6
JAN 92	990 125	264.0	180.5	346.0
FEB 92	1 095 231	292.1	198.8	237.8
MAR 92	1 199 000	319.7	239.1	327.4
APR 92	1 247 683	332.7	237.3	286.8
MAY 92	351 298	93.7	246.1	220.6
JUN 92	175 111	46.0	209.6	185.8
JUL 92	329 128	86.4	185.4	142.5
AUG 92	152 572	40.0	171.5	75.2
SEP 92	527 587	138.5	176.2	198.8
OCT 92	996 159	261.5	193.5	272.7
NOV 92	310 616	81.5	183.2	289.0
DEC 92	660 372	173.3	176.8	174.6
JAN 93	1 014 132	266.9	180.5	346.0
FEB 93	964 514	253.8	198.8	237.8
MAR 93	1 435 199	377.7	239.1	327.4
APR 93	1 341 802	353.1	237.3	286.8
MAY 93	469 745	123.6	246.1	220.6
JUN 93	162 623	42.8	209.6	185.8
JUL 93	624 892	164.4	185.4	142.5
AUG 93	405 215	106.6	171.5	75.2
SEP 93	741 748	195.2	176.2	198.8
OCT 93	1 040 731	273.9	193.5	272.7

TABLE 2 : WATER REQUIREMENTS AND WATER SUPPLIES AT KOURANI-BARIA I, MARCH 1992 - AUGUST 1993

Month		Volume of water pumped (m^3/month)	Equivalent mean depth of water pumped (mm/month)	Mean monthly evapotranspiration (mm/month)
MAR	92	1 587 400	373.4	186.3
APR	92	1 288 800	303.3	206.6
MAY	92	346 100	81.4	190.8
JUN	92	222 100	52.2	188.5
JUL	92	534 000	125.6	162.9
AUG	92	1 123 000	264.2	150.2
SEP	92	1 525 200	358.8	155.9
OCT	92	1 369 800	322.4	160.4
NOV	92	473 200	111.3	143.3
DEC	92	721 000	169.6	141.4
JAN	93	1 319 400	310.3	143.7
FEB	93	1 873 500	440.9	187.4
MAR	93	1 431 100	336.7	186.3
APR	93	1 534 500	360.9	206.6
MAY	93	415 700	97.9	190.8
JUN	93	485 500	114.4	188.5
JUL	93	485 500	114.4	162.9
AUG	93	1 003 700	236.2	150.2

TABLE 3

Water deliveries to tertiary canals in Saga, GMP2 and GMP3, 23 September - 24 October 1992

Tertiary canal no. delivered	Area under irrigation (ha)	Volume of water delivered (m^3)	Equivalent depth of water (mm)
T1	8.95	50 645	565.8
T2	8.70	43 009	494.4
T7	9.85	43 240	439.0
T8	10.45	37 962	363.3
T14	10.50	39 571	376.9
T15	10.50	32 108	305.8

Source : Reference 7

Note :

1 Penman potential evapotranspiration over this period is about 191 mm.

2 Volume of water delivered is estimated on the basis of measurements of flow discharge rate at each tertiary head, and time of pumping recorded at pump station.

TABLE 4

COST AND PRODUCTIVITY OF WATER AT SAGA, 1992

				Dry season	Wet season	Year
1	Area cultivated		ha	378.0	379.4	379.4
2	Energy cost		fCFA	6 813 700	4 982 700	11 796 400
3	Other water costs		fCFA	6 683 500	6 688 800	13 372 400
4	Total water costs	(2)+(3)	fCFA	13 497 200	11 671 600	25 168 800
5	Energy cost per ha	(2)/(1)	fCFA/ha	18 026	13 132	31 158
6	Other water costs per ha	(3)/(1)	fCFA/ha	17 629	17 629	35 310
7	Total water cost per ha	(4)/(1)	fCFA/ha	35 707	30 761	66 468
8	Volume of water pumped		m^3	5 642 600	2 398 400	8 041 000
9	Volume of water pumed per ha	(8)/(1)	m^3/ha	14 928	6 321	21 249
10	Paddy production per land unit		kg/ha	4 425	5 100	9 345
11	Paddy production per water unit	(10)/(9)	kg/m^3	0.284	0.807	0.440
12	Cost of water per unit volume	(4)/(8)	fCFA/m^3	2.39	4.87	3.13
13	Cost of water to produce 1 Kg paddy	(12)/(11)	fCFA/kg	8.42	6.03	7.11
14	Potential paddy yield without irrigation		kg/ha	-	1 000	1 000
15	Marginal paddy yield due to irrigation	(10)-(14)	kg/ha	4 245	4 100	8 345
16	Marginal production per water unit	(15)/(9)	kg/m^3	0.284	0.649	0.393
	Value of production @ fCFA 65 per kg :					
17	Total	(11)x65	fCFA/m^3	18.5	52.5	28.6
18	Marginal	(16)x65	fCFA/m^3	18.5	42.2	25.5