Irrigation and Drainage Systems 7: 99–112, 1993
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Reducing schistosomiasis infection risks through improved drainage

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Accepted 31 January 1993

Key words: Benue valley, Cameroon, health risks, drainage, schistosomiasis, snail control, water management

Abstract. The discharge of irrigation drainage water through a natural depression in the Benue valley of North Cameroon, has created a permanently flooded habitat for freshwater snails which transmit schistosomiasis. The risk of transmission of schistosomiasis for people living near this depression has considerably increased. In close cooperation and consultation with the local population the depression was reconstructed in order to destroy snail breeding sites and to use the available land and water for agriculture and fisheries. Results indicate that the availability of a manageable water supply is welcomed by the villagers, especially because it makes dry-season horticulture a more attractive and profitable endeavour. In addition the production of fish is appreciated because it provides a cheap additional source of protein for local consumption. Snail populations have dramatically decreased in numbers after the reconstruction of the depression, showing that an integrated approach to drainage problems can result in increased production while reducing health risks.

Introduction

Intensification of floodplain agriculture by controlling seasonal floods and construction of irrigation schemes is an important option for development in the semi-arid regions of Africa. Most of Africa's large rivers have already been dammed and large irrigation schemes have been constructed. The spread of some well-known water-related diseases such as malaria and schistosomiasis is often associated with irrigation, as these schemes include permanent breeding sites for disease-transmitting mosquitos and snails. There is a wealth of literature on the relationship between irrigation and health. An extensive review on this subject is given by Oomen, Wolf & Jobin (1990). Many authors state that the link between schistosomiasis and irrigation is most strongly associated with faulty or inefficient irrigation, poor land preparation and lack of free drainage, rather than with irrigation *per se*. Engineering measures to control schistosomiasis is to a considerable degree just good irrigation practice (e.g. Mather

1984; Imevbore 1987; Webbe 1988). This paper focuses on a possible solution to health problems created by drainage of irrigation waste-water.

Irrigation in Africa is hampered by budget difficulties, often resulting in neglected drainage systems and minimal investments in canal construction (earth instead of concrete lining, etc.). Any additional measures which are advocated (whether for public health reasons or any other desirable purpose) are likely to be subjected to cost scrutiny. One of the very few quantitative studies describing a drainage system which was reconstructed because of health reasons comes from Iran. Here, drainage improvement, combined with land reclamation in swampy areas, and agricultural development resulted in a positive cost-benefit ratio and a decrease in schistosomiasis prevalence (Oomen et al. 1988). According to Abernethy (1987) there is increasing need for demonstration and measurement of the benefits of these alternative policies in irrigation development. Although no data on economic benefits are available at this stage of the project described hereafter, the approach is similar to the Iranian case.

The project area

In 1982, the Benue river in Northern Cameroon was dammed near Lagdo for the generation of hydroelectricity and the development of irrigated agriculture. As a result, seasonal flooding of the former floodplain of the Benue downstream of the Lagdo barrage has greatly diminished, and the plain has lost part of its production functions, e.g. fisheries, cattle grazing, dry season agriculture, etc. Floodplain fishery for example, was an important source of revenue and proteins for the local population, but this activity virtually ceased to exist. By preventing floods and storing water, the Lagdo barrage has created the conditions for the transformation of a considerable area into a large-scale irrigation development scheme which will eventually include thousands of hectares of irrigated fields. In 1987, a first 200 ha scheme was put into operation on the right bank of the Benue near the village of Gounougou. At the moment of writing another 800 ha scheme near the villages of Ouro Doukoudje and Bessoum is under construction. To save on construction costs, drainage water is discharged through natural floodplain depressions which as a consequence turn into permanent marshy areas due to the presence of drainage water throughout the year. These habitats are optimal breeding grounds for freshwater snails, some of them being intermediate host species of schistosomiasis. Data on schistosomiasis suggest a rise in prevalence (percentage of population infected per age class) over the past three years compared to neighbouring villages where there was no influence of irrigation development (Robert, unpubl.; Slootweg 1991a). Also malaria mosquitoes reproduce in large numbers in such areas. In the case of Gounougou, with a depression all along the village, the nuisance caused by mosquitos is enormous and malaria prevalence has risen dramatically (Slootweg & van Schooten 1989).

In 1987, a pilot project started in the village of Gounougou with the dual objective of (1) restoring the former floodplain fish production and (2) controlling intermediate hosts of schistosomiasis (Slootweg 1991b). In close cooperation with the villagers a reconstruction plan for the drainage system was developed and implemented between September 1988 and June 1991. During this period a sampling programme on the snail hosts of schistosomiasis was carried out in order to monitor the effects of this reconstruction on the snail populations. A key element in this project is water management. With water available throughout the year, the depression can be turned into a productive area for fishculture and horticulture; however, this requires regulation of the water running through the depression. The establishment and reproduction of snails can to a large extent be controlled by effective water and environmental management, such as clearing of vegetation, regular drying of reservoirs and canals, and high water velocities. In this article we show that an effective drainage system can have economic benefits, as well as reduce the irrigation related health risks.

The water flow around Gounougou before reconstruction

The map in Fig. 1 illustrates the different flows of water around Gounougou. The schematic cross-section in Fig. 2 gives an impression of the relief in the area. Before the construction of the irrigation scheme, rainwater accumulated on the plains East of Gounougou before passing a threshold at the centre of the village (**A**) and entering the depression. Ultimately the depression discharged into the Benue (**B**). The irrigation scheme that has been constructed on these plains in 1987, uses this same drainage system. As a result, the rainwater coming from the hillsides is now blocked by the main irrigation canal (**ctm** in Fig. 1) where three culverts lead the water under the canal towards the irrigation scheme. Initially in the construction of the scheme no provision was made for a proper drainage of rainwater south-east of the scheme, although the design provided for a 4m wide stormwater drain. The maximum run-off in a one in ten years rainy season is calculated to be 15–20 m^3s^{-1} during 4 hours (Timmerman 1989). The heavy rains of 1988 clearly demonstrated the need for better drainage structures. The accumulated rainwater was blocked on its course by the secondary irrigation canal (**C**), endangering the embankment of the scheme. Ultimately the water found its way towards the Benue, by breaking a road embankment.

In the rainy season of 1988 the Lagdo reservoir reached its maximum capacity and the spillways of the barrage had to be opened for the first time at 1800

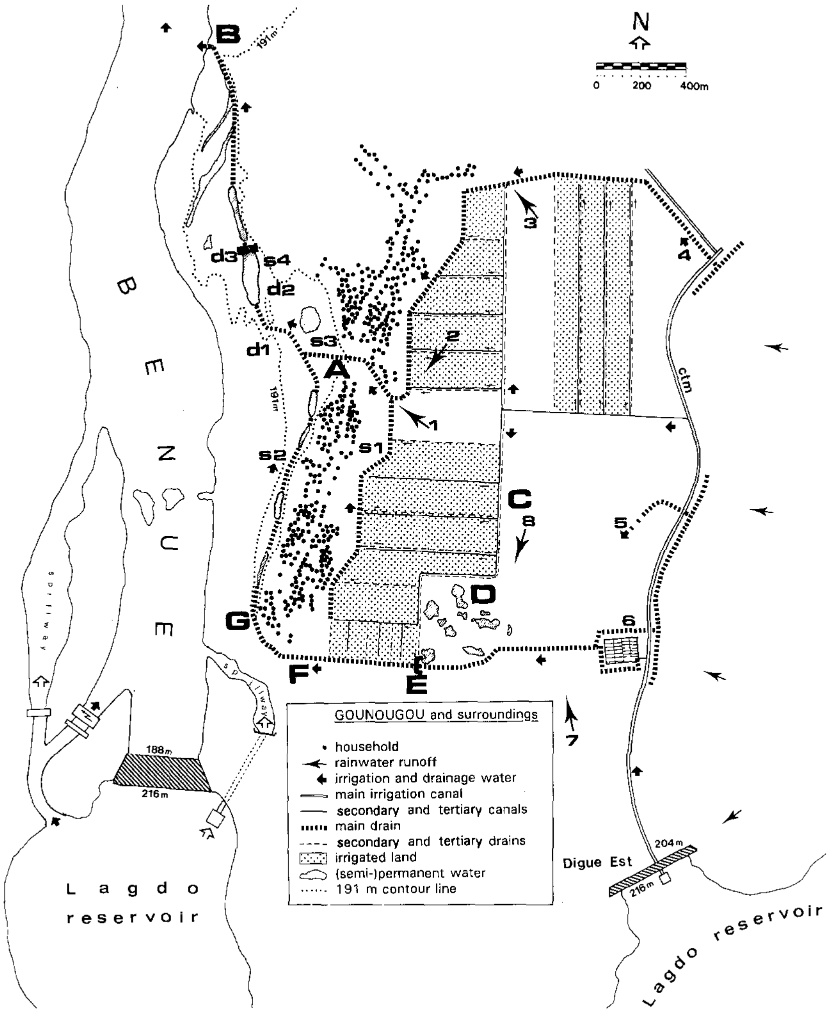


Fig. 1. Waterflow in and around the Gounougou irrigation scheme after reconstruction. Indicated are locations refering to the text (**A** to **G**), general direction of rainwater run-off (arrows **1** to **8**), dam sites (**d1**, **d2**, **d3**) and snail sampling sites (**s1** to **s4**).

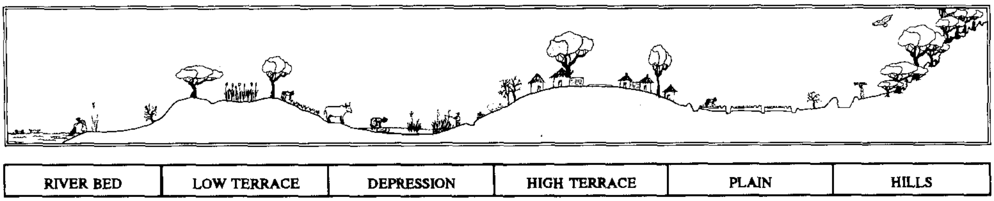


Fig. 2. Schematic West to East cross-section of the Gounougou area. The low terrace is reserved for rain dependent cultures (millet, groundnuts, etc.); the depression is shown in its former state without central canal; the high terrace is occupied by the village and main road; the plain is used for irrigated rice and polyculture; the wooded hills provide fire wood (modified after Leeuwerik, 1989).

m^3s^{-1}. The depression near Gounougou filled up to the 191m contour line (Fig. 1), and many parts of the downstream plains flooded. The following years less than 1000 m^3s^{-1} were released, causing a rise of 2m in water level (190m) which did not result in floodings.

The intermediate hosts of schistosomiasis

A sampling programme in the region (Greer et al. 1990; Slootweg et al., in press, a) revealed the presence of three snail species that are known to be intermediate hosts of vesical schistosomiasis (*Schistosoma haematobium*), *i.e. Bulinus globosus*, *B. truncatus* and *B. senegalensis*, and one intermediate host of intestinal schistosomiasis (*S. mansoni*), i.e. *Biomphalaria pfeifferi*. Furthermore *Bulinus forskalii*, the vector for *S. intercalatum*, was found very often. This parasite only occurs in the rainforest zone of Central Africa (including the south of Cameroon). *Lymnaea natalensis*, host of blood flukes of the genus *Fasciola*, were registered regularly. Especially for cattle this parasite constitutes a health risk.

B. forskalii and *B. senegalensis* are known to live in habitats that can be dry for long periods (up to seven months). *B. forskalii* is also known as a rapid colonizer of newly created habitats. The two species can only be distinguished unequivocally through iso-enzyme analysis. A detailed study revealed that *B. forskalii* is present throughout the year, but that *B. senegalensis* can only be found during the rainy season in temporary habitats (Mimpfundi & Slootweg 1991). *B. globosus, B. truncatus* and *L. natalensis* colonize new habitats less rapidly but can withstand considerable fluctuations in habitat. *Biomphalaria pfeifferi* prefers permanent habitats without too many disturbances. (Brown 1980; Wibaux-Charlois et al. 1982).

The principal reproduction period for snails in this region is the cooler dry season (December–March), when water temperatures are optimal for reproduction (between 20°C and 25°C). The second half of the rainy season (July–September) is a minor reproduction period. The rotation in the irrigation scheme more or less follows a similar seasonal time schedule with two crops a year: a dry season (November–March) and a wet season crop (May–October). Two snail reproduction peaks can be recognized in the irrigation schemes, coinciding with the rotation cycle in rice culture.

Analyzing the problems

Because the success of the project relied to a large extent on the participation of the villagers, regular village meetings were organized with the chiefs and other interested persons. Although most people thought the introduction of irrigated agriculture was good for the village, some problems related to the recent developments were raised by the inhabitants. Their main concerns included the loss of fishing grounds, the loss of agricultural land for traditional cultures, and the destructive feeding behaviour of the hippopotamus family residing near the barrage. Based upon the physical characteristics of the region, the foreseeable health risks, and the problems stated by the villagers, additional technical demands which the drainage system should meet were formulated:

1. The 2 m^3s^{-1} of maximum water discharge from the irrigation scheme should be able to pass through the main drain that crosses the village (**A**).
2. The system must be also able to deal with the maximal flow of rainwater during a once in a decennium downpour (data taken from Timmerman 1989):
   - main drain at village level: 6.5 m^3s^{-1} (arrows 1 + 2 + 3 + 4 in Fig. 1);
   - accumulation in southern area: 15.3 m^3s^{-1} (arrows 5 + 6 + 7 + 8 in Fig. 1).
3. If the adjacent land around water reservoirs is to be put into agricultural use in the dry season, the water level in the reservoirs must be stable, so the system must include regulation devices.
4. Fish must be prevented from escaping towards the Benue.
5. Since high water velocities and regular drying prevent snail breeding, a drainage canal has to be dug through the depression zone; this also facilitates harvesting of fish.
6. In order to further reduce snail (and mosquito) breeding, the creation of marshes near the village must be prevented; the water level in the depression should never overflow the embankment of the canal.
7. During (rare) periods of maximal discharge of the spillways at the barrage, the rising water enters the depression at the outlet (**B**) and floods the entire depression. This implies that all structures in the depression should be able to withstand inundations of the area.
8. Water contact should be limited as much as possible in order to prevent schistosomiasis infection. From the village, the low terrace between the river and the depression can only be reached by wading through the permanently filled depression (Slootweg et al., in press b); a pedestrian bridge would reduce the frequency of water contacts considerably.
9. An alternative grazing area for the hippopotamus family should be found in order to prevent the destruction of gardens around the depression; the same applies to cattle.

Design

Storage of rainwater

As already stated the accumulation of rainwater in the southern part of the scheme poses a threat. Instead of digging a huge and expensive canal towards the Benue, capable of discharging some 15 m^3s^{-1}, a storage basin in the clay quarry (**D**) lying at the lowest point east of the scheme has been planned. A small cofferdam with removable plates and grille (**E**) at the outlet diminishes the waterflow to a maximum of 1 m^3s^{-1} through the drainage canal and prevents fish from leaving the basin. This would allow for a canal (**F**) of smaller dimensions, saving considerably on construction costs. The capacity of this 19 ha basin is large enough to store the maximal run-off in a decennial four hours downpour. Requirements 2, 4 and 5 are met by these measures. At the end of the rainy season the outlet structure (**E**) can be closed, storing water for dry season purposes. The area is unsuitable for agriculture, but it is a good grazing area for both cattle and hippopotamus. The perennial floodplain grasses *Echinochloa stagnina* ("bourgou") and *Oryza longistaminata* (wild rice) constitute an important protein source for herbivores (requirement 9). By storing water in the deeper clay-pits for dry season use, the cattle can be restrained from drinking in irrigation canals. At the end of the dry season the basin can be drained and fish can be collected. The original plan foresaw a drop structure towards the Benue, that would require an enormous investment (> US$ 25,000), as the difference in height in water level between the canal and the Benue is three meters over less than 50 m. A deviation of the drain (**G**) towards the southern part of the depression proved to be a much cheaper solution. A beneficial side-effect of this deviation is that water from the storage basin (**D**) can be reused in the depression.

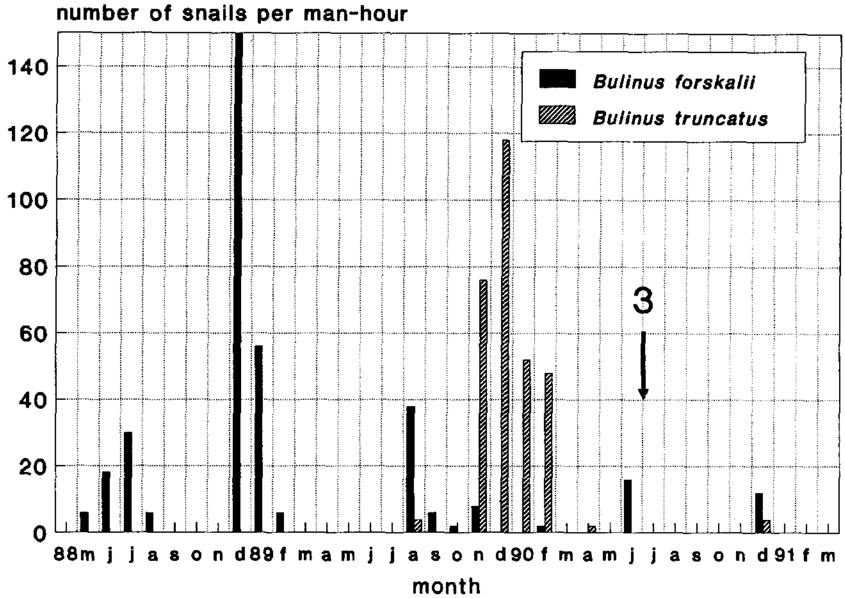
The depression

The modification of the depression was implemented in four steps; after each step the reactions of the villagers were assessed at village meetings.

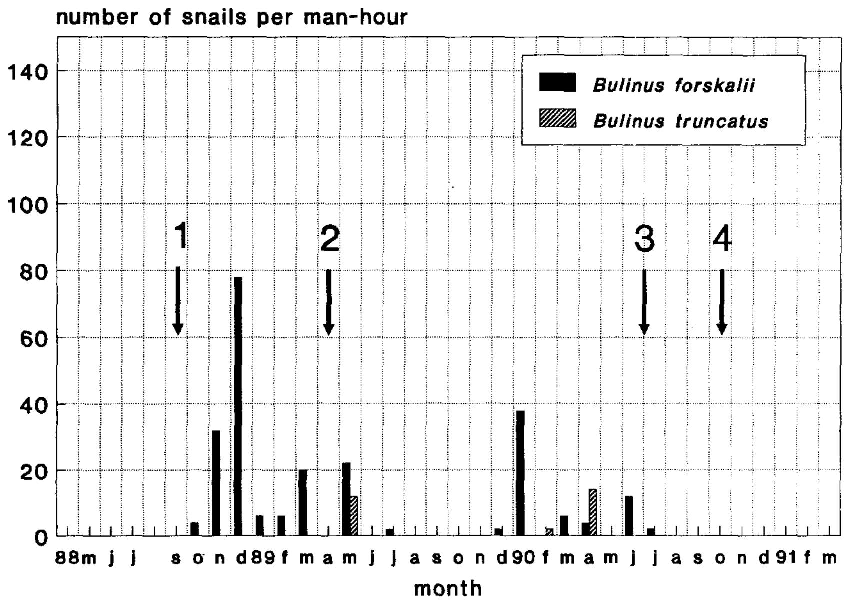
Step 1: In september 1988, three sandbag dams were built by manual labour by the villagers at sites **d1**, **d2**, **d3** to meet requirements 3 and partly 4. Surplus drainage water could spill over the dams. The rise in water level created an even larger swampy area along the village, but at least the level was steady and the depression now could be used for agricultural purposes and fisheries.

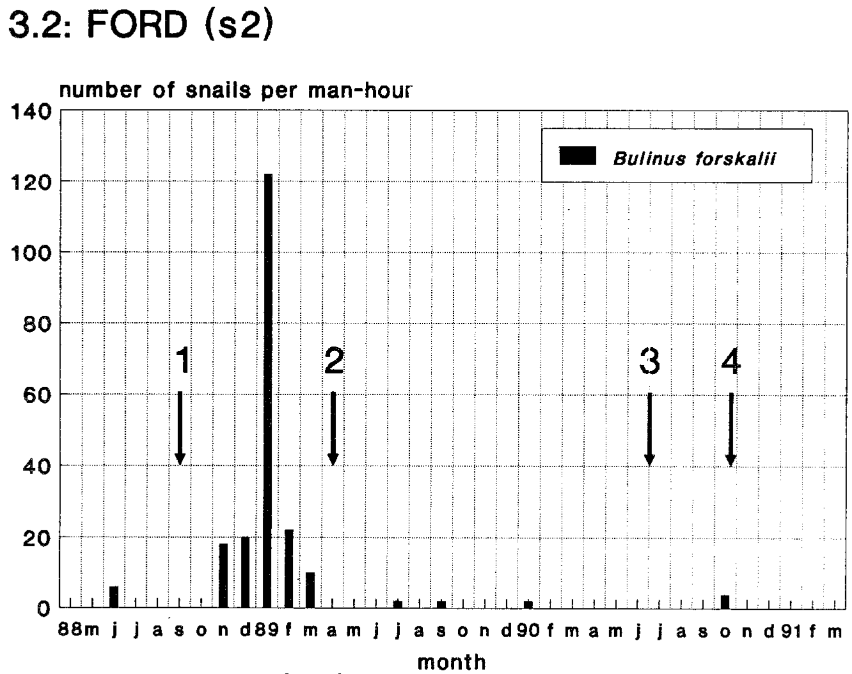
Step 2: In april 1989 the dams were demolished in order to drain the depression and to estimate the fish production. The evolution of schistosomiasis snail populations were continuously monitored.

3.1: MAIN DRAIN (s1)



3.3: DRAIN ENTRANCE (s3)





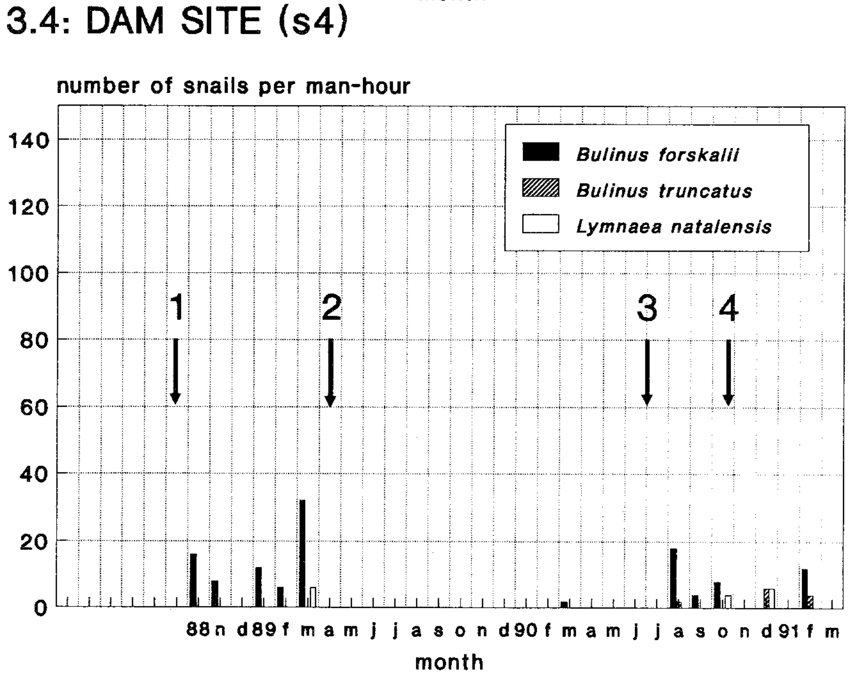


Fig. 3. Influence of stepwise reconstruction on the development of snail populations at four sampling sites in the drainage system of Gounougou. Step 1: building of sandbag dams at sites **d1**, **d2** and **d3**; step 2: demolition of sandbag dams and partial drainage of depression; step 3: cleaning of main drain and completion of the canal through the depression; step 4: closure of cofferdam at site **d3**.

Step 3: In the first half of 1990 a canal was dug all the way through the depression towards the outlet into the Benue (from **G** to **B**). Drainage could now be established at 188.5m, enabling complete drying out of the depression. Requirements 1, 2 and 5 were met by this canal.

Step 4: Following the digging of the canal, a cofferdam was constructed at site d3. When the valves are closed the water level will rise to the 190m level, creating a small reservoir behind the dam and filling the canal. Small trenches perpendicular to the main canal were dug in order to irrigate the garden plots along the canal. Furthermore a pedestrian bridge was constructed over the canal. With these final constructions in step 4, a proper management of the depression meeting all requirements (1–8) has become possible. Between the southern end of the depression and the dam about 15 ha of land has become suitable for dry season cultivation, and a 6 ha reservoir has been created for fish production.

Results

Schistosomiasis intermediate hosts

During three years the drainage system has been sampled for snails on a monthly basis. Four sites were chosen: the main drain near the school (**s1**), the ford in the middle of the depression (**s2**), the entrance of the main drain (**s3**) and the pool near the dam site (**s4**). The different steps in the reconstruction of the depression can be recognized in the dynamics of the snail populations (Figs. 3.1–3.4):

- Main drain (**s1**; Fig. 3.1): In the first year of snail sampling (April '88 – March '89) two distinct reproduction peaks of *Bulinus forskalii* can be recognized. In the second year these two peaks were found again. A more important finding was that a large population of *B. truncatus*, the intermediate host of vesical schistosomiasis, has established itself. After the dredging of the drain in June '90 (step 3), snails have been encountered only once in December 1990. The establishment of *B. truncatus* has been halted by this activity.
- Ford (**s2**; Fig. 3.2): After the damming of the depression (step 1) an important population of *Bulinus forskalii* was found in the main reproduction season. After the demolition of the sandbag dams (step 2) the ford virtually dried up. Since then the snail population has not recovered.
- Entrance of main drain (**s3**; Fig. 3.3): *Bulinus forskalii* was found in large numbers in the first reproduction season following the installation of the sandbag dams (step 1). Drainage of the depression (step 2) only had a very temporary effect because a large amount of water coming from the irriga-

tion scheme still flows into this part of the depression. Within a month *B. forskalii* reestablished itself and, more importantly, *B. truncatus* was found for the first time. The next major reproduction season, starting in december 1989, showed a return of both *B. forskalii* and *B. truncatus*. It was only after the canalization of the depression (step 3) that snails disappeared and did not reappear in the following months.

- Dam site (s4; Fig. 3.4): As for the other two sites *B. forskalii* was resident in the pool near the sand bag dam. *Lymnaea natalensis* was also registered once in march 1989. Drainage of the area (step 2) caused a temporary disappearance of snail populations but the permanency of a reservoir at this site stimulated the proliferation of vector snails. After the closure of the dam in october 1990, three snail species were found regularly (*B. forskalii, B. truncatus*, and *L. natalensis*) but in much lower quantities compared to sites s1, s2 and s3 before the modification of the depression.

Summarizing the results of the reconstruction of the depression zone along the village, one can say that the risk of schistosomiasis transmission has considerably diminished. However, a potential transmission site with low numbers of snails remains present near the dam at considerable distance from the village.

Additional beneficial effects

After 1989, the storage basin (D) has performed well and no inundations or damages caused by excess rainwater were recorded. In the dry season the area was visited daily by several herds from the village and by herds of nomadic pastoralists, together counting several hundreds of heads (sheep, goats and cattle). Occasionally tracks of nightly grazing hippopotamus were found. Unfortunately the animals also continued to visit the depression zone causing much damage to vegetable gardens.

The installation of the sandbag dams (step 1: October '88 – February '89), and the creation of a reservoir with stable water level provided the villagers a basis for dry-season agricultural activities. Without stimulation from outside 18 gardens for horticulture and 7 plots of spontaneous rice cultivation were created, together covering about 3 ha. These activities proved that villagers would be interested in the creation of a management structure for the depression, because of the economic benefit derived from the dry-season activities around the water. This active participation of the village population is a prerequisite for an effective management of the depression zone.

After the first harvest, the sandbag dams were demolished (step 2) in order to drain the depression. The remaining pools were fished by the villagers who used a variety of traditional techniques. Especially groups of women were very successful in trapping fish in shallow water with the help of woven baskets. In a one day joint effort the estimated catch was 500 kg.

The second dry season (November 1989 – April 1990) was lost because of the modification of the depression. In june 1990 the canal was completed (from **G** to **B**), so the depression could be drained to the level of 188.5m (step 3). In the same period the main drain of the irrigation scheme was dredged and cleared of vegetation in order to improve water discharge and to eradicate a resident snail population. Four months later the construction of the dam (**d3**) was finished, and the gates closed at 190m (step 4). At this level the water does not overflow the embankment of the canal, so the former swamps are now permanently dry, and a larger area of arable land has become available. Again the inhabitants of Gounougou spontaneously started making gardens, but discussions between autochthones and immigrants on land-use rights had become very intense. Clearly the value of this formerly useless marshy land had risen considerably. Immigrants constitute by far the majority in the village. The provincial authorities had promised free access to land, so the immigrants put much pressure on the autochthones to be allowed to use depression lands but the latter still refuse to give up their traditional land rights. Obviously the village needs time to adjust to the new situation.

Fish production decreased to ± 250 kg, which more or less represents the yearly natural production of a 6 ha waterbody (estimated at 50 kg/year/ha; Welcomme 1979). The initial catch of 500 kg was abnormally high because the depression had never been entirely drained before, and fish from different year-classes could be caught. One must keep in mind that figures on fish catch represent minimal production levels. In reality the production is much higher because throughout the year people are regularly seen fishing in the area. Very rough estimates of fish production in the entire Gounougou watershed (excluding the Benue river and Lagdo reservoir) add up to 1–2.5 tons per year.

Conclusions

Although it is still too early to draw a definite conclusion on the Gounougou pilot-study, some important observations can already be made. The modification of the drainage/depression system alongside the village has drastically reduced the number of snails. Both the pedestrian bridge and the dam are used very often by people and cattle to cross the depression, thus reducing the water contact frequency. As a result of the decrease in snail density and the number of water contacts, the risk of schistosomiasis transmission has been reduced. Consequently, it is likely that the depression no longer constitutes a health risk for the village. This reduction of snails can only be maintained if the area is properly managed in future by the villagers themselves. This is obviously the most difficult part of the project, but since the agricultural and aquacultural production capacity also depends on proper management, this economic incentive might secure a continued active village participation.

Since schistosomiasis transmission is a slow process and other transmission sites occur in the region one cannot expect a sudden lowering of schistosomiasis prevalence in the village. Monitoring will be continued in the coming years in order to register any change in the prevalence of the disease. Furthermore, anecdotical evidence given by people living near the depression, suggest that the numbers of mosquitos have decreased.

The ongoing creation of new irrigation schemes in the Benue valley and beyond is reason enough to continue the monitoring of this pilot study. Hopefully the results obtained sofar will be used in the planning and realisation of these new activities. The ideas presented in this study cannot just be copied to other areas; each irrigation and drainage system has its own characteristics, such as topography, water management, and crop rotation. Consequently, also snail populations differ. Moreover, the people living and working in a scheme can have very different traditional skills, hierarchical structures, etc. towards irrigation management. If one wants to study the possibilities of reducing health risks by optimizing the use of water resources, it is imperative to study each irrigation system individually. Health risks will probably always be associated with irrigation development, but these risks can be minimized. We would like to stress the necessity to invite experts in other disciplines to comment on newly designed irrigation systems before they are actually constructed. Usually these people are confronted with the problems after the scheme has already been built, making it very difficult to suggest any changes in the system. In this study we were confronted with topics related to fisheries, agriculture, animal husbandry, wildlife management, vector biology, and extension work. Evidently irrigation engineers cannot address all these areas because many of these problems are not in their field of expertise. Therefore, an integrated multidisciplinary approach to irrigation development is in our opinion necessary. This will insure that the benefit of increased agricultural production will not be offset by health and other problems that are so often associated to irrigation in developing countries.

Acknowledgements

The authors wish to thank director A. Liman of the MEAVSB for his support in personnel and logistics. Chef Halidou Tchioutou and the inhabitants of Gounougou have contributed to this project in many ways. Valuable comments on a first draft of this paper were given by Wouter de Groot, Jeroen van Wetten, and Wim Slootweg. This study was financed by the Dutch Directorate General of International Cooperation and realized under the responsibility of

the MEAVSB (Mission d'Etude et d'Aménagement de la Vallée Supérieure de la Bénoué), Garoua, Cameroon.

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