Agricultural intensification and ecological threats around small reservoirs

Authors

Cecchi Philippe. IRD UR 167 CyRoCo, Université Montpellier, France.

Leboulanger Christophe. IRD UR 167 CyRoCo, UMR 5119. Université Montpellier, France.

Bouvy Marc. IRD UR 167 CyRoCo, UMR 5119. Université Montpellier, France.

Pagano Marc. IRD UR 167 CyRoCo, LOPB, Centre d'Océanologie de Marseille, France.

Nimy Victor. IRD UR 167 CyRoCo, Burkina Faso.

Scope: questions/ challenges the tool addresses

"Well-designed small reservoirs have the potential to improve the lives of people who grow irrigated crops and fish, water livestock, and use water in their households" (SIWI 2006). This positive statement needs to be revised, however, when farming practices near reservoirs generate deleterious by-products that downgrade water quality in aquatic ecosystems, and reduce the level of goods and services that reservoirs are intended to produce.

In Burkina Faso and particularly in the Nakambé basin (where the highest density of small reservoirs is found)[1], vegetable production for urban markets and for export is increasing in importance. This situation is also found in surrounding countries (see Fromageot et al. 2006, for Côte d'Ivoire as example). This is not surprising: providing surface water in rural areas is a clear invitation for local communities to harness the resource for productive purposes.

The increasing number of small reservoirs appears directly related to the (largely urban) demand for vegetables and other high-value products, whose cultivation is associated with growing a use of inputs, in particular fertilizers and pesticides. Agricultural intensification and urban expansion both lead to increased levels of anthropogenic inputs into reservoirs. Ultimately, these human activities tend to undermine reservoirs' integrity and sustainability.

How to cope with this? First of all, by being informed! That is our goal here.

Target group of the tool

Planners and managers of small reservoirs

Tool: description and application

The many ecological disturbances in aquatic ecosystems linked to anthropogenic pressures (loss of biodiversity, harmful algal blooms, hypoxia, disease, and decline in fisheries, etc.) have been well documented (Conley 1999, Paerl et al. 2003). In freshwater ecosystems, for example, the indiscriminate use of pesticides is known to disturb important biological functions (Relyea 2005, Lürling and Roessink 2006).

[1] See a separate tool that discusses an Atlas of Lakes and Reservoirs in Burkina Faso

Although in African inland waters, knowledge of such hazards is somewhat limited, some information is available. Early insights came from studies conducted in Northern Côte d'Ivoire (Cecchi 2007a) in an area where the dominant commercial crop is cotton, the production of which requires large quantities of insecticides. In the same area, cash crop (onion) production developed rapidly and at a large scale around small reservoirs. The production of this crop also resulted in the use of large amounts of xenobiotics. (Figure 1).

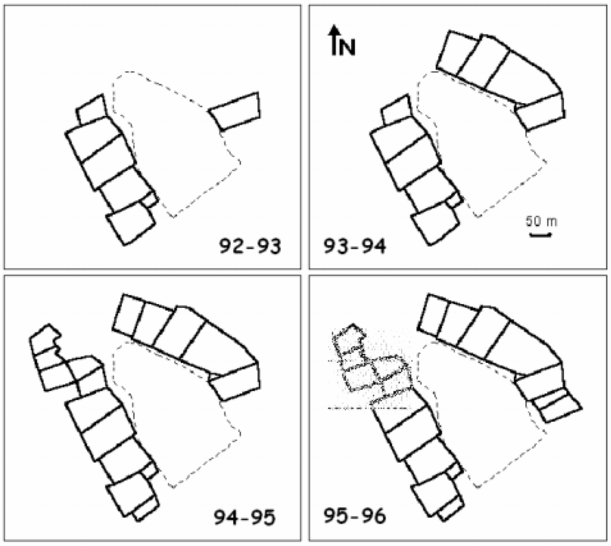

Figure 1: Progressive saturation of surrounding areas by cash crop production (onion) around the Korokara Termitiere reservoir (N: 09°54'45" – W: 05°36'44") in northern Côte d'Ivoire.

The growing use of toxic products and the movement of their residues within the environment are of concern in watersheds and in areas surrounding reservoirs. Pyrethroids, used for cotton and onion cultivation, are of particular concern. Experimental approaches have revealed that these insecticides accumulate in reservoir sediments (Table 1).

Table 1: Indirect evaluation of pyrethroid presence in water and sediment samples collected (March 2000) in the Korokara Termitiere reservoir, North Côte d'Ivoire, by assessing the degree of toxicity on mosquitoes (Survival in %).

Mosquito variety	Survival	Sediment + reservoir water (1)	Sediment + reservoir water (2)	Sediment + distilled water	Distilled water	Water from downstream wells
Resistant	Larvae	94.1	87.5	96.2	95.9	93.2
	Adults	**84.7**	**70.8**	**85**	**89.7**	**86.4**
	Sample size	*85*	*72*	*80*	*97*	*88*
Sensitive	Larvae	92.7	81.6	93.3	93.5	92.2
	Adults	**27.3**	**27.5**	**45.2**	**62.0**	**62.6**
	Sample size	*110*	*98*	*104*	*108*	*115*

Two different strains of mosquitoes were used to assess the degree of toxicity of these pyrethroids. One strain of mosquito was resistant to pyrethroids; the other was not. Eggs of the two strains were exposed to samples of reservoir sediment, reservoir water, and water from a shallow well located downstream from the reservoir dam. The survival rates for all three treatments were compared and referenced against distilled water. No differences between treatments were expected for the resistant strain, regardless of the presence or absence of insecticide. Reduced survival of the sensitive strain was understood to indicate the presence of toxicity. Results are unambiguous:

- no effect of treatments on the resistant strain
- survival < 28% with "sediment + lake water"
- survival < 50% with sediment only
- no significant effect of water from the well

Although the robustness of the test was slightly weakened by the relatively poor survival (62%) of the sensitive strain in distilled water, test results clearly indicated the presence of pyrethroid compounds in sediment samples.

In Burkina Faso, few data are available on the use of pesticides. One “semi-official” source of data was AFAMIN (www.afamin.net, discontinued to date) that listed compounds authorized for use in agriculture in Western Africa for 2002-2005. A wide range of products appears to have been available in Burkina Faso for controlling insects and pests. However, as commonly is the case, no information regarding their composition was provided by local suppliers (Eddleston et al. 2002). Among listed compounds, highly toxic chemicals such as thiram, paraquat, cypermethrin, and deltamethrin are found in various forms.

Experiences with pesticide contamination in similar ecosystems, for example in bordering Ghana (Osafo and Frempong 1998; Ntow 2001, 2005; Ntow et al., 2006; Amoah et al., 2006), suggest that impact on surface waters is likely to occur in Burkina Faso. However, even when target compounds have been identified and quantified, their toxicity to aquatic life in tropical ecosystems is typically difficult to predict because of a lack of data (Wiktelius et al. 1999).

More information can be collected with bioassays using water concentrates that include their eventual pollutant. Such experiments were done using solid-phase extraction (SPE) cartridges to concentrate dissolved materials from water sampled in the peri-urban Loumbila reservoir in Burkina Faso. This reservoir supplies drinking water to the capital Ouagadougou (Leboulanger et al. *in press*). The concentrates were applied to plankton organisms (bacteria, phytoplankton, and zooplankton, from cultures or samples from other lakes) to evaluate their potential toxicity. They were applied as classical dose-effects bioassays in which the most concentrated test conditions were twice the natural concentration.

Concentrated extracts showed clear short-term toxic effects for all types of microorganisms tested. For aquatic bacteria, the tests had an obvious effect on abundance and activity, with rapid recovery related to a shift in the bacterial community composition. For phytoplankton, the lowest concentration used in the test that caused significant change (compared with the control) was two thirds of the normal concentration. For zooplankton, the concentrated water extract had a dramatic impact on the two tested species, with a 100% mortality rate after 24 hours exposure at all concentrations. Growth rates of tested organisms were also dramatically affected (see figure 2 for *Moina micrura*, cladoceran zooplankton largely widespread in small reservoirs and used here as target organism).

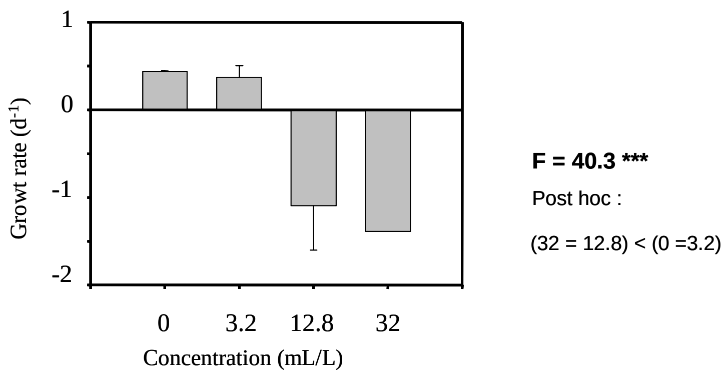

Figure 2: Chronic toxic effects of concentrated water samples from the Loumbila reservoir on *Moina micrura* growth rate after five days of incubation. (Loumbila, N: 12°29'25" – W: 01°24'18").

The observed effects of the Loumbila extract on phytoplankton and zooplankton are similar to the combined effects of paraquat (herbicide) on phytoplankton and deltamethrin (insecticide) on zooplankton (experimentally assessed, results not shown here; see Lahr et al. 2000). Despite the absence of data on the type of chemical molecules present in the extract, it is obvious that the extract contains a cocktail of pollutants that drastically affects organisms living in the aquatic ecosystem (Leboulanger et al. *op. cit.*). These results raise concerns about the actual chemical pressure exerted on small reservoirs in Burkina Faso, being mindful that contamination can be detrimental to aquatic life, to the economic value of ecosystems, and also to human health. That the observed effect of the concentrates mimics the application of a cocktail of pollutants from agricultural inputs is particularly disturbing when one considers the on-going intensification and diversification of agricultural practices around most small reservoirs.

Figure 3 illustrates land use around the Toukoumtouré small reservoir in the Nakambé basin. During the 2006/07 growing season, 6.7 hectares were intensively exploited, corresponding to about one quarter of lake surface area during the high water season, and nearly equal to the total lake surface area at the end of the dry season.

The volume of water used for irrigating these fields during one season (45,000 - 50,000 m^3) was found to correspond to about 1/5 of the total volume of the lake (220,000 m^3). As is apparent from Figure 3, different crops were cultivated, each with a different pest control regime. About ten pesticides were reported by farmers to be commonly used, two of them being lambda-cyalothrin and acetamipride (Figure 4). Herbicides were not used. Several other products, mainly illegal copies of manufactured pesticides were also used, but in quantities that could not be determined.

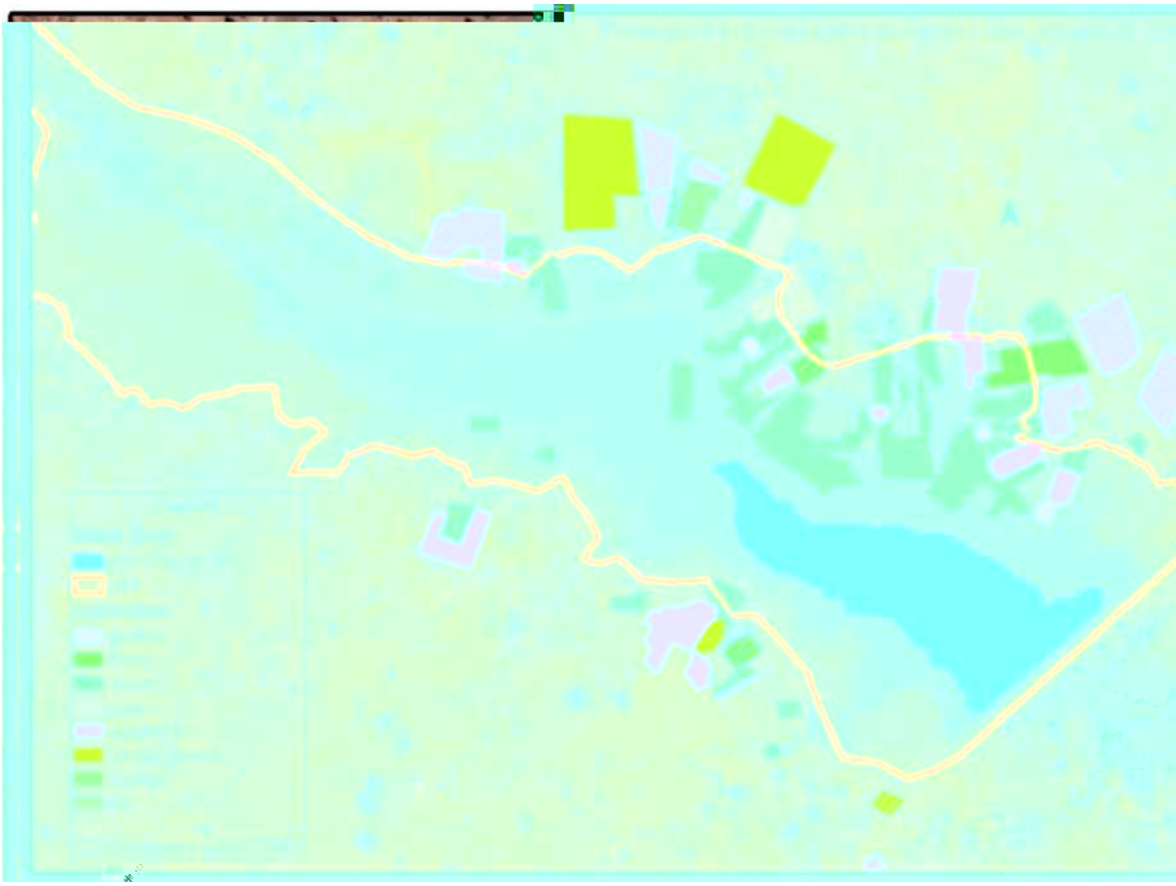

Figure 3: Distribution of fields devoted to vegetable production around the Toukoumtouré reservoir (Nariarle Basin, Burkina Faso; N: 12°15'19" – W: 01°19'00") during the dry season 2006-07 (Hyrkäs and Pernholm 2007).

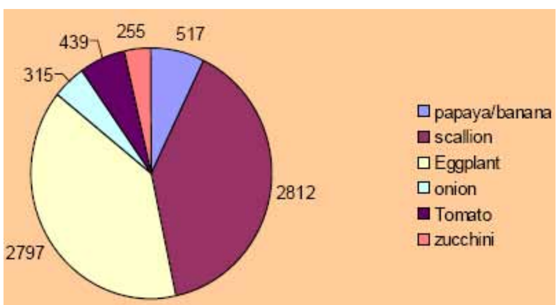

Figure 4: Total amount of the insecticide lambda-cyalothrin (g) used during the cultivation period (dry season 2006-2007) around the Toukoumtouré reservoir (Nariarle Basin, Burkina Faso; Hyrkäs and Pernholm 2007).

Toukoumtouré is one of the smallest reservoirs in the Nariarlé basin, itself a sub-basin of the Nakambé. This basin is located south of the capital Ouagadougou, spreads over with 1500 km^2, has 50 reservoirs, and is home to 150,000 inhabitants (Figure 5). Because of its peri-urban location and close proximity to urban markets, the cultivation of irrigated vegetables here has increased dramatically. Toukoumtouré illustrates in miniature what is taking place in the other 50 reservoirs.

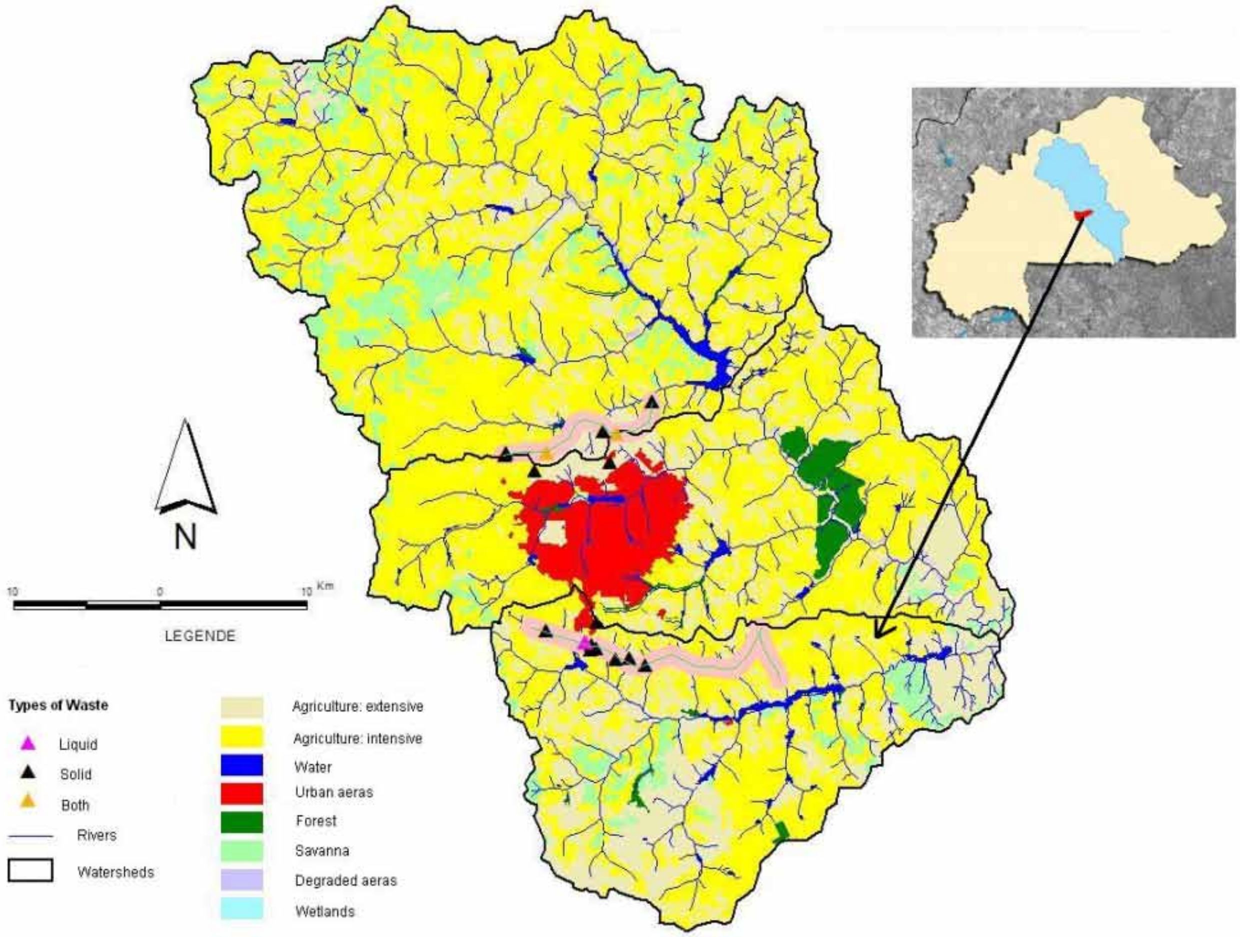

Figure 5: Localization of areas where urban garbage and sewerage are distributed. Limits of sub-basins, Loumbila North and Nariarlé South of Ouagadougou (red patch), are indicated.

Even at this small scale, hundreds of kilograms of different pesticides are used annually for irrigated agriculture. Because of is peri-urban location, this example may given an exaggerated sense of the problem, nonetheless it highlights trends that need to be considered everywhere in Burkina Faso.

The amount of a pesticide applied to a crop may not reflect its impact on aquatic ecology. In a

Lessons learned

Research on the consequences of agricultural intensification and urban expansion is clearly justified. Trends that drive irrigated agriculture towards more intensive land and water use will further aggravate the problem. Because peri-urban production of high value irrigated crops is profitable, there is increased investment by urban residents in these systems. Such investment raises questions about impacts on land tenure, inflation, and access to land and water among local stakeholders (Ouedraogo 2006) – in fact, about the very nature of agriculture near small reservoirs. Crop production has now become a lucrative business, and the quest for profits may have begun to undermine legal considerations – witness the abundance of illegal pesticides.

There is a lack of information regarding about intensification near small reservoirs. A project, recently funded by the Danish Embassy in Burkina Faso (Cecchi, 2007b) aims to document current practices and develop typologies about environmental risks that intensification poses to small reservoirs.

Recommendations

In order to reduce the risk ecological hazards associated with intensive irrigated agriculture around small reservoirs, the following steps should be considered:

- Diversify access to water resources to reduce direct household consumption of surface water. Accelerate access to efficient sanitation services.
- Strengthen controls and restrictions on the use of illegal copies of pesticides. Eliminate harmful products whose health impacts on farmers and their families are even more worrying than impacts on ecosystems.
- Be flexible in applying IWRM: norms of water quality should be defined and applied differently in accord with different water uses
- Involve local management organizations in IWRM, keeping in mind the hydrological flows among small reservoirs and the way water is used and repeatedly re-used.
- Conduct sustained ecological monitoring of water bodies and carry out scientific studies devoted to on-site toxicological assessment.

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Contacts and Links

Philippe CECCHI, IRD - UMR 5119, Université Montpellier 2, Place Eugène Bataillon, CC 093, 34095 Montpellier Cedex France. Philippe.Cecchi@ird.fr

Christophe Leboulanger for pesticides, IRD - UMR 5119, Université Montpellier 2, Place Eugène Bataillon, CC 093, 34095 Montpellier Cedex France. leboulan@mpl.ird.fr

Cecchi Philippe, Leboulanger Christophe, Bouvy Marc, Pagano Marc, Nimy Victor

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