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**Endemic diseases and agricultural productivity:
Challenges and policy response**

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Abstract:

Contrary to Asian countries, the agricultural sector in Africa had not benefited from the green revolution success. After a long time of disinterest in the agriculture sector in Africa, several voices arise now in favour of greater efforts towards this sector. Several studies tend to show the crucial role of agriculture in African countries' growth and highlight the huge need of increasing the productivity in this sector. If increase in agriculture productivity requires both an expansion of irrigated areas and the adoption of high yield varieties, those innovations and their high development could be the source of negative health (and environmental) effects.

Using a mega-analysis, this paper highlights first the links between health, disease and development and then agricultural productivity. The literature review shows that the negative effect of bad health was not systematically checked, and that the intensity of this effect depends of the disease, but also of the work productivity and the existence or not of a coping process. The second part of the paper focused on the development of high intensive agriculture as a risk factor for farmers' and rural inhabitants' health. This survey shows that whether irrigation and fertilizer and pest intensive use could be considered as highly health (and environmental) risk factors, appropriate control measures (such as for examples systematic maintenance of irrigation canals, alternate wetting and drying of irrigated fields or integrated pest management) considerably reduce this risk, while at the same time, increase the agriculture productivity.

Summary

Introduction

I – The role of agriculture in development

II – The effect of endemic diseases on agricultural sector productivity

Question: are endemic diseases a risk factor for farm productivity?

2.1 Health, disease and development

2.2 Endemic diseases and agriculture productivity

III – Effect of intensive agriculture on endemic diseases

Question: is intensive agriculture a risk factor for health?

3.1 Health risks associated with water resources development: parasitic diseases

3.2 Health risks associated with intensive insecticides and pesticides use: respiratory and parasitic diseases

IV – Policy response

4.1 How to increase farm productivity?

4.2 How to prevent intensive agriculture health effect adverse?

Conclusion

INTRODUCTION

A glance at the Millennium Development Goals underlines the role of agriculture in development. Three of these goals are directly or indirectly focused on agriculture, through the eradication of extreme poverty (goal 1), and the potential consequences of its development through health with endemic diseases (goal 6) and the environment (goal 7, see box 1).

A review of the literature shows that if the development of agriculture is essential for the economy, its expansion could have, through the environment, direct and indirect negative effects on health. Intensive agriculture owing to irrigation systems may cause, for example, water-borne diseases, such as malaria, schistosomiasis or onchocerciasis.

Despite a huge increase in the financing of malaria control programmes, this parasitic disease remains the priority of public health in Africa. It is highly probable that the target of the MDGs will not be reached in 2015. Malaria deaths per 100,000 people have increased between 1970 and 1995, and the proportion of child under-five receiving malaria treatment remains very low among the poor (figures 1 and 2).

Box 1:

Goal 1: Eradicate extreme poverty and hunger

Target 1: Halve, between 1990 and 2015, the proportion of people whose income is less than one dollar a day.

Target 2: Halve, between 1990 and 2015, the proportion of people who suffer from hunger.

Goal 6: Combat HIV/AIDS, Malaria and other diseases

Target 8: Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases.

Goal 7: Ensure environmental sustainability.

Target 9: Integrate the principles of sustainable development into country policies and programmes and reverse the losses of environmental resources.

Source: WHO

Insert Figures 1 and 2

On the one hand, to eradicate extreme poverty and hunger, we need to increase production and consequently land productivity. On the other hand, increases in land productivity partly result from water resource development and intensive use of agriculture inputs which are considered health risks. For that reason, the fight against rural poverty could be a brake into the health MDG achievement.

Studying the relations between endemic diseases, development and agriculture productivity allows us to discuss, first agriculture's role in development (section I), then the effect of health in general, and of endemic diseases in particular, on agriculture productivity (section II), before speaking about the effect of the development of agriculture on health and the environment (section III). The fourth section is focused on policy responses.

I – The role of agriculture in development

Historical observation of the agricultural transformation showed a uniform and pervasive decline of agriculture's importance. This unavoidable decline allowed the misperception that agriculture is unimportant (Timmer, 1995). Consequently, investing in agriculture has not been considered as a priority for several decades. The low productivity in the agricultural sector in Africa highlighted this fact.

In the sixties, the green revolution, by introducing high-yielding varieties of wheat and rice and high technologies, contributed to improving agricultural productivity in Asian countries. This technological

revolution was a great success. After that, some of these countries observed a decline of agriculture's importance, as in the rest of the world. This decrease contributed to the decline of interest in agriculture. In Asia, resources devoted to agriculture decreased and were oriented towards the industrial sector and high technologies as observed in China for example (Nyberg, 2002). Few voices arose in favour of greater efforts towards the agriculture sector in Africa: developments in agriculture should follow as in Asian countries.

But, contrary to Asian region, Africa has not benefited from a green revolution. High yield varieties and irrigation systems were slowly adopted. Numerous studies, focused on the sources of Asian agriculture productivity (Azam, 1996; Bera and Kelley, 1990; David and Otsuka, 1990; Kalirajan and Shand, 1985), were undertaken in order to draw lessons for African countries. A debate arose in the literature and concerned:

- Crops: should farmers be incentivized to grow cash crops instead of food crops, while price incentives were not verified and risk aversion induced smallholders to insure their food security (Lele, 1989; Lele and Argawal, 1989)?
- Production scheme: should total water control, including dam building and the creation of lakes or large reservoirs there be in spite of land salinity (Diemer and van der Laan, 1987), or should partial water control be developed in spite of lower crop yields (Barnett, 1984)?

New technologies require understanding farm-level decision-makers and creating economic incentives. Timmer (1995) states that, during the 1970-1980' period, agricultural policy was a market-liberalization strategy. This strategy should provide adequate price incentives to agricultural producers. For him and for some other authors (Kawagoe, Hayami and Ruttan, 1985), the major constraint limiting agricultural development was when policies impeded, rather induced, appropriate technical and institutional innovations.¹

Since the eighties, the World Bank drew attention to this sector highlighting the role of agriculture in growth and found a positive and significant links between the agricultural share of GDP, agricultural growth and GDP growth in developing countries (World Bank, 1982). Those links could be found in Benin, Cameroon, Central African Republic, Ghana and Togo, where the growth of the agriculture sector between 1980 and 2005, has been real and higher than the growth of GDP (Table 1). But it was not the case for all countries. The growth of the agriculture sector was weak and sometimes negative for example in Botswana, Namibia, Rwanda and Uganda. If in the 1980s, agriculture growth seems have no link with the GDP growth (Figure 3a), after 1990, the relationship appears more evident as shown in Figures 3b and 3c. One argument for this change is that the growth of agriculture productivity may create important demand for the outputs of other sectors (fertilizer, transportation, commercial services, World Bank, 1982, and Timmer, 2002).

Insert Table 1

More recently, numerous people are those who consider that African agriculture, long neglected, may merge as a constraint to growth. It appears that, despite higher land and agricultural labour productivity since 2000, the rates of respectively 5% and 3%, required for a sustainable growth, have been reached in less than one third of African countries (World Bank, 2007). The 2008 World Development Report focused on the agriculture sector and asked, for Africa, the questions such as:

- Given agriculture changes, in the past 20 years, whether new challenges and opportunities arose;

¹ The role of prices was also noted (but with a different effect) by de Souza Filho, Young and Burton (1998) when they worked on the determinants of farmers' decisions on whether or not to adopt low-external-input and sustainable agriculture technology. They found that changes in relative prices were influential as a decline of output prices allowing incomes' decrease induced farmers to switch to sustainable technology, more cost-effective.

- How to capture cost effectively new sources of agricultural growth;
- How to contain agriculture's negative environmental effects (World Bank, 2007).

So, the necessity of agricultural productivity growth is recognised both for improving rural household welfare (by increasing incomes and then living conditions) and achieving sustained economic growth. "No country has been able to sustain a rapid transition out of poverty without raising productivity in its agricultural sector. Despite this historical role of agriculture in economic development, both the academic and donor communities lost interest in the sector, starting in the mid-1980s, mostly because of low prices in world markets for basic agricultural commodities. Growth in agricultural productivity not only can increase farm incomes, it also stimulates linkages to the non-farm rural economy, causing economic growth and rapid poverty reduction" (Timmer, 2002).

Insert Figures 3a, 3b, 3c

Literature on this topic is growing and links between growth, poverty and agricultural or farm productivity are now again more studied. Above the debate on the role of agricultural productivity on the growth process through non-farm activity or rural migration,² agricultural productivity is concerned as a tool in the fight against poverty (Christiaensen, Demery and Köhl, 2006). Except few examples, all countries in the world (OECD countries, Timmer 2005; Asian countries, Huffman and Orazem, 2007) started economic growth by an agricultural transformation based on technical change. If agriculture productivity growth requires both an expansion of irrigated area and adoption of high yield varieties, those innovations or technology and their high development could be the sources of negative health (and environmental) effects. Those risk factors are the topic of the following sections.

II – Effect of endemic disease on agricultural sector productivity

As for agriculture, the role played by human capital and more specifically, by health in economic growth and development is considered as essential. Beyond population well-being, the economic benefit of disease control programmes or health improvement was considered as one criterion among others for local or national policy-making. The assumption here is that bad health has a cost, both direct and indirect. The direct cost is the financial cost, bound up with curative and preventive care, as well as catastrophic costs that push them deeper into poverty (Xu *et al.*, 2003). The indirect cost is the economic cost, associated with a decrease in productivity, production or income as a consequence of illness. In this section, we have focused on this latter cost. Before tackling the question of disease's effect on agriculture productivity, more general links between disease and development are presented.

2.1 – Health, disease and development

In the fifties, the role of health and more specifically of endemic or parasitological diseases on growth or development was considered as known. Before World War II, malaria, still a high cause of mortality and morbidity in Europe, Latin America and North Africa, was considered as a root cause of development and became the public health priority. In 1955, the World Health Organization claimed that malaria was an economic disease. Consequently, the financing of malaria control programmes drastically increased, contributing to large scale vector control and preventive treatment (Delacollette and Rietveld, 2006). In the same vein, onchocerciasis (river blindness) was considered in the 1970s, as

² However, there is some debate around the effect of agricultural productivity on the development of non-farm activities (a step in the development process) and then a possible increase of rural out-migration. The debate is whether non-farm activities are highly dependent from agricultural productivity, in which case, investing in agricultural technology allows high returns to investment (Foster and Rosenzweig, 2008; Christiaensen, Demery and Köhl, 2006). Investigations are also done on the role of the liberalization trade (in fertilizer, irrigation equipment, etc.) on crops productivity increase and prices and then on the welfare of the poor (Klytchnikova and Diop, 2006).

a disease which had forced inhabitants to migrate, preventing the cultivation of fertile lands in West Africa. This idea contributed to the financing and launching the Onchocerciasis Control Programme (OCP), over 11 countries in 1974. And, as for malaria, the true relationship between this disease and development was not really proved for almost two reasons. First, economists had paid little attention to health as an economic variable (Packard, 2001). Second, only a few studies demonstrated that disease control over the general population or reducing disease prevalence would generate economic growth or could increase worker productivity.³ Moreover, in 1968, Barlow showed that due to the population increase thanks to malaria control, the GDP per capita will decrease at long term.

Consequently, this field of research was partly abandoned before interest revived with Sen's works on human capabilities and with the emergence of AIDS. The international interest in poverty reduction and the proclamation of the millennium development goals also contributed to a re-emergence of studies focusing on the links between health, welfare, and development. In 2001, the Commission on Macroeconomics and Health (WHO, 2001) concluded in its report that diseases are a barrier to economic growth.

Numerous studies, using theoretical and empirical methods, found that bad health and diseases have negative effects on growth or living conditions. Partly due to the difficulty of measuring the multiple dimensions of health and consequently global health⁴, the economic effects of health have been more often studied through more commonly-used health indicators such as life expectancy, infant mortality, or nutrition indicators. Economic effects of health were also found through the effect on education and on future incomes. It is well-known that malnutrition will retard physical (stature) and mental development. Several authors found that a delay in childhood development (height), or low birth weight would have an impact on future wages or labour productivity (Deolalikar, 1988; Sahn and Alderman (1998); Strauss and Thomas, 1998; Huffman and Orazem, Berham, 1999; Behrman and Rosenzweig 2004). With the development of national household surveys, (such as the Demographic Health Surveys undertaken in numerous countries), researchers are more likely to undertake studies on the economic effects of health at household or individual level. Authors showed that health shocks, based on self-reported functional activity limitation and disability days, make households vulnerable and rush them into poverty. Schultz and Tansel (1997) found that disability days reduce wages by at least 10% and hours by 3%. Gertler and Gruber (2002) found that Indonesian families are unable to insure their consumption against major illness shocks in the absence of an insurance scheme. Christiaensen, Hoffmann and Sarris (2007) estimated that one-third of rural households in Tanzania lost, due to a health shock, an eight percent of welfare after using saving and aid. Liu et al. (2008), using data from longitudinal China Health and Nutrition Surveys, found that healthy households have higher income than those in poorer health.

Adverse health economic effects were also studied through endemic and parasitological diseases. Gallup and Sachs (2001), through cross-country regressions of the 1965-1990' period, found a negative relation between malaria and growth. Taking into account among others, initial poverty and tropical location, they found that countries with intensive malaria grew 1.3% less per person per year. They argued that wiping out malaria in sub-Saharan Africa could increase that continent's per capita growth rate by as much as 2.6% a year. Bell, Devarajan and Gerbasch (2003) showed how AIDS by killing young adults and depriving children of parents' loving care, knowledge and capacity to finance education, will cause drastic economic damage.

And during the last decade, a consensus in academic and policy circles held "that disease environment and health conditions lie at the root of large income differences across countries today, and argues that improving health will not only improve lives but will by itself spur rapid economic growth"

³ The difficulty to assessing health economic effects on farm activity is due to the coping process phenomenon (Conly, 1975 for example) and the underemployment of active population.

⁴ After the pioneer work of the Ghana Health Team Project (1981), the World Bank and the WHO in 1993 proposed a new health indicator, the Dalys (Disability adjusted life years). Calculated for about 140 diseases and the WHO regions, one expected almost ten years before Dalys was calculated by country (WHO, 2002). And since now, it is the only one year where estimation by country is available.

(Acemoglu and Johnson, 2006). However, more recent work contradicts this consensus or at least show again that the links between health and development are more complex. In fact, if those links are not really questioned (Bloom, Canning and Sevilla, 2004; Bloom and Sachs, 1998; Gallup, Sachs and Mellinger, 1999, Barro, 1997; Kloos et al. 2008), voices will arise against a systematic and universal relation. The example of the AIDS disease illustrates this purpose. Despite the facts that poverty increases the biological susceptibility to HIV, in the same way as all other infectious diseases, absence of instruction is a handicap for the efficiency of HIV prevention (Lachaud, 2007). On the other hand, macroeconomic studies (O'Farrell, 2001; Lachaud, 2007; Tsafack, 2008) as well as microeconomic ones (Ainsworth, Semali, 1997; Lachaud, 2007; Tsafack, 2008), underline a positive link between HIV prevalence and living standard.

In the same vein, the finding of a negative health effect at the macroeconomic level was controversial. In their paper, Acemoglu and Johnson (2006), using international data from the epidemiological transition period, do not find that an increase in life expectancy at birth (due to drastic decrease in mortality), had a significant economic impact. They find that an increase in life expectancy had a small initial positive effect which grows over the post epidemiological transition, but not enough to compensate for the increase in population. Consequently, life expectancy increase does not led to a significant increase in per capita economic growth. This result joins those of Barlow (1968) with regard to malaria eradication and of Over (1992) with regard to economic effects of AIDS. Bell, Bruhns and Gersbach (2006), using a model with overlapping generations (1950 to 1990) and simulations (ending in 2050), show, contrary to their previous work on this topic, that the economic effect of AIDS will not be so catastrophic as predicted for the economic growth in Kenya.

While this recent literature sheds doubt on claims that unfavourable health conditions are the root cause of the poverty of some nations, authors however agree with the fact that global efforts to combat poor health conditions in less developed countries can be highly effective (Acemoglu and Johnson, 2006). Empirical relations between health, growth and poverty are not so clear or at least difficult to evaluate. Some reasons could be put forward and among them the complex interrelations between health, disease, and productivity, as shown in Figure 4. The next paragraph concerns the effects of diseases on agriculture productivity.

Insert Figure 4

2.2 – Endemic diseases and agriculture productivity

We saw that the agriculture sector is or should be a priority sector for policy-makers. Investigating on the determinants of agriculture productivity is a step towards the first MDG. As healthy populations are supposed to be more productive, health is one of those determinants. But as we will see, the assessment of diseases impact on agriculture productivity is not obvious.

The literature on the effect of endemic or parasitic diseases on agriculture was relatively extensive between 1960 and the end of the eighties. Effects of diseases were estimated either on production (Foster, 1967; Barbosa and da Costa, 1981; Audibert, 1986), on productivity (Baldwin and Weisbrod, 1974; Weisbrod and Helminiak, 1977; Workneh *et al.*, 1993), reallocation of labour and land (Fenwick and Figenshou, 1972; Conly, 1975), or on reducing physical ability (Collins *et al.*, 1976, Spurr *et al.*, 1977; Brohult *et al.*, 1981; van Ee and Polderman, 1984). Results of those studies were contrasted.

Baldwin and Weisbrod (1974) examined the productivity effects of five parasitic diseases (schistosomiasis, ascariasis, trichuriasis, strongyloidiasis, and hookworm infection) in Santa Lucia. Earnings per week were used as a measure of productivity and the presence of schistosomiasis and each of the other four parasitic infections as measure of disease morbidity. The four hypotheses, tested by regressions where number of diseases entered as explanatory variables, are that diseases:

- 1) reduce weekly earnings per week;
- 2) cause workers to shift to physically less demanding jobs;
- 3) reduce productivity per day;
- 4) reduce the amount of labour supplied per week

Results are that parasitic infections, except schistosomiasis, appear to cause few statistically significant adverse effects on agricultural labour productivity, but may affect the quality and quantity of leisure time and relationships within the household. Pursuing this study, Weisbrod and Helminiak (1977) found, three years later that schistosomiasis exerted a lower effect on earnings (14 percent of the daily earnings of male workers against 30 percent previously) while ascariasis exerted a higher effect.

Due to coping processes and reallocation of intra-household labour, Conly (1975) did not find any malaria effect on Mexican farmers' production nor did Gateff *et al.* (1971) in Cameroon with both malaria and schistosomiasis. On the contrary, Audibert (1986), using longitudinal field surveys among rice-growers' households in North Cameroon, found that urinary schistosomiasis had a negative effect on rice production while malaria had not. Wang'Ombé and Mwabu (1993) also found no direct effects of malaria upon income or agricultural production in Kenya, although they think, this result does not imply that malaria has no consequence on household welfare.

Several explanations could be advanced:

- i) Lack of data regarding adequate measure of morbidity or invalidity (Guyatt and Evans, 1992; Bennett, 1993);
- ii) Lack of data on labour substitution (hiring or within family substitution (Wang'Ombé and Mwabu, 1993);
- iii) Lack of innovation in statistical analysis (Rosenfield *et al.*, 1984).

The recent literature on the effect of endemic diseases on agriculture productivity is less numerous⁵, may be because assessing those links needs multidisciplinary studies. Further, most recent works on this topic mainly concerned malaria and schistosomiasis while the interest for the links between AIDS and agriculture arises (Gillespie and Kadiyala, 2005; Gillespie, 2006).

⁵ Studies on economic effect of health in the agriculture sector should be found, as for example that of Sarris, Savastano and Christiaensen (2007) in Tanzania. But health indicator does not concern endemic diseases.

If some authors use an indirect approach for assessing potential economic losses due to diseases (Umeh *et al.* 2001; Asare-Afrane *et al.*, 2004; Girardin *et al.*, 2004), others tried to deal with the above underlined inadequacies (Audibert and Etard, 1998; Audibert *et al.* 2003a, 2003b; Packard, 2001).

Umeh *et al.* (2001) working on urinary schistosomiasis in Nigeria, showed that low infection households use on average, other determinants of land use being controlled for, more land than heavy infection households. Asare-Afrane *et al.* (2004) focused on urban areas in Ghana and compared individuals' days lost due to malaria according to their living place: city locations without irrigated agriculture, city locations with irrigated urban vegetable production, peri-urban locations with rain-fed agriculture. They found that the number of reported malaria episodes and days lost due to illness was significantly higher in urban areas with irrigated agriculture in both seasons (rainy and dry) for all age groups. Concerning malaria again, negative correlations were found between total yield and the number of days described sick due to malaria (Girardin *et al.*, 2004) in Cote d'Ivoire.

Assessing the impact of schistosomiasis among rice-grower households, Audibert and Etard (1998, 2003c) used a quasi-experimental design including health treatment. The effect of the treatment was assessed according to economic output (paddy yield), and five resource variables (family and hired labour productivity, family and hired labour intensity and farm size). Results showed that health improvement has no direct short term effect on rice production, but affects the household's use of its labour resources and its ability to utilize resources. Relative to the untreated group, the number of family workers-days available increased by 69 per hectare and the size of cultivated land by 0.47 hectare in the treated group. Further investigations have shown that the net improvement of family labour productivity observed in the treated group has been used, not to increase the yield of the main cash rice-crop, as might be expected, but to extend the cultivation of other more quickly profitable crops, such as market-gardening crops.

These results illustrate:

- 1) the key role of the coping process, observed by Conly in the 1975s, in masking the direct economic effects of disease;
- 2) the economic benefit of reducing the burden of disease by increasing time available for developing agricultural activities or non-farm activity (see the debate on the growth process relatively to non-farm activity).

The economic effect of malaria was again studied but in Cote d'Ivoire (Audibert *et al.*, 2003a, 2003b, 2009). Field data were collected by the authors between 1997 March and 1998 February in the savannah zone of Korhogo and in 1999 in the forest zone of Danane. Field surveys were carried out on 700 and 800 respectively rural households living in three rice production irrigation systems among 21 villages. Two malaria morbidity indicators were used: *Plasmodium falciparum* infection rate and high parasite density infection rate. Methodological approach for estimating malaria economic effect was slightly different according to the papers.

- The first paper (savannah zone) tried to assess the impact of malaria on farm household property or assets (Audibert *et al.*, 2003a). The question was: by weakening individuals, does malaria reduce productive capacities and income workers, and consequently limit their assets accumulation? Data on household assets (farming equipment, livestock and durable consumer goods) and other household characteristics such as malaria morbidity were collected and introduced into a log linear regression models. Findings showed a significant negative correlation between high density infection rate and the property values. They confirm that by reducing the living standards of households, malaria is a limiting factor for assets accumulation.

- The second paper (Audibert *et al.*, 2003b) assessed the effect of malaria on cotton-crop development (savannah zone) using a production frontier model assuming that unhealthy (due to malaria infection) cotton-grower households should be less efficient than healthy ones. Findings confirmed the assumption, and highlighted a critical threshold above which malaria had a negative effect on technical efficiency in the cotton crop. Farm households in which the proportion of actives with a high density (more than 499 trophozoites/ μ L of blood) of *Plasmodium falciparum* was higher or equal to 25%, were less efficient than farm households in which this proportion is lower.

- The third paper (Audibert *et al.*, 2009) assessed the effect of malaria on coffee and cocoa productions and yields. After controlling for malaria endogeneity and village heterogeneity, a two-stage least square regression analysis on coffee and cocoa production were used. Contrary to results on the cotton-crop, malaria infection seems to have no effect on coffee and cocoa crops, neither directly through the production or indirectly, through a coping process such as the resort to hired labour. Several arguments were advanced, and among them, the fact that coffee and cocoa crops are less labour consuming than rice or cotton crops.

The last paper discussed here is that of Packard (2001). Studying the links between malaria and land cultivation in South Africa, while having adopted an historical point of view, Packard (2001) found that malaria may have been a barrier to economic development in the lowveld regions of South Africa. But, she estimates that its impact on agricultural production varied by race and class. Malaria was more a barrier for poor whites than large-scale white commercial farmers. The benefits of malaria control after World War II were limited in the sense that poorer whites and Africans did not expand their economic activities such as extended fertile land cultivation.

III – Effect of intensive agriculture on endemic diseases

Increasing land productivity needs the adoption of new technology or systems of cultivation such as high yield variety crop, fertilizers, pest management use, and irrigation systems and dams construction. Irrigation in allowing double cropping and decreasing the uncertainty of relying on water supplied by rainfall, is the answer in the fight against poverty. Studying the source of growth performance of non-rice crop sectors in India, Janaiah, Achoth and Bantilan (2005), for example confirmed the role of irrigation in total factor productivity. Their findings were that the contribution of technological progress was considerably higher in Indian regions where modern varieties (MVs) were adopted under irrigated/semi-irrigated conditions.

Between 1965 and 1995, the percent of irrigated lands in the world increased from 11% in 1965 to 17% in 1995 (Schoengold and Zilberman, 2004) and the percentage change from 1973 to 1988 varied between less than 15% (Nigeria, Sudan, Peru, Chile, Venezuela) and more than 45% (Madagascar, Mali, Brazil, Columbia, Hunter *et al.*, 1993). In Asia, the part of irrigated lands increased a lot (16% in 1965, 31% in 1995, 42% in 2000), contrary to Africa where percentage of irrigated lands, despite of some large projects (Mali, Cote d’Ivoire, Nigeria), was very low (5% in 1965, 6% in 1995, and 2000, Schoengold and Zilberman, 2004; FAO website, Table 2). Moreover, 70% of irrigated land in Africa was in four countries (Egypt where 98.6% of cropped land is irrigated, Madagascar, Nigeria and Sudan, Hunter *et al.* 1993). In other words, Africa has great potential for land productivity by increasing irrigated lands. The use of chemical fertilizer and pesticides is also considered as a means to significantly increasing land productivity.

Insert Table 2

Agriculture has a role in reaching the first of the eight MDGs (combat extreme poverty). If the transformation of this sector has been less easy in Africa than in Asia (see section I), the green revolution has been more successful in some countries. For example, due to the adoption of HYVs, agricultural productivity has drastically increased in Zimbabwe (Thirtle *et al.*, 1993).

Water resources development and intensive fertilizer and pesticide use were both considered having several adverse effects:

- as irrigated lands need dam construction and other water resources projects, a concern about parasitic diseases and inhabitants contamination as well due to migratory movements and population resettlement, migrants contamination;
- as pesticides are applied to food crops, a concern about contamination of farm produce due to residues they can leave (FAO, 2008).

Figure 5 presents and summarizes the motives of intensive agriculture development and its potential negative effects on health. Argumentation and comments are developed below.

Insert Figure 5

3.1 – Health risks associated with water resources development: parasitic diseases

As a consequence of the pressure of population increase in developing countries, water impoundment and irrigation systems have been implemented in developing countries. Large, medium and small dams were built in Africa between 1960 and 1980 and irrigated land area increased from 8,261 hectares in 1965 to 11,146 hectares in 1988 (Hunter et al., 1993). With the development of water resources and irrigation systems, numerous voices arose in the literature and criticised dam construction considered as the main culprit in the emergence or re-emergence of parasitic diseases.

Before arguing about health risks of water resources development, it may be useful to quickly present what are the parasitic diseases associated with water resource schemes. Mainly, four parasitic diseases, filariasis, malaria, onchocerciasis and schistosomiasis, are associated with water. Schistosomiasis is linked more closely to human living conditions such as the absence of adequate sanitary facilities. People pollute the environment by unsanitary habits. They acquire schistosomiasis infection through repeated daily contact with water during fishing, farming, swimming and recreational activities. Then, an increase in the density of human population due to migratory movements and population resettlement will exacerbate its transmission. Malaria, filariasis, and onchocerciasis are transmitted to humans through the bite of infected mosquitoes or black flies which breed in staged water, fast-flowing streams and rivers.

Construction of dams (large or small) and development of irrigation systems may modify the habitats, breeding patterns and consequently, the density of intermediate snail hosts (in the case of schistosomiasis) and insect vectors (Hunter et al., 1993). This modification constitutes per se a health risk and explains why so many voices arose against dams and irrigated agriculture. But, if examples of negative health effects were well-known in the past, examples of the absence of health negative effects could be also found.

- **Negative health effects of water resources development**

Two famous examples have been often cited in the past, as the disaster of dam construction and irrigation systems. They were the Aswan Dam in Egypt and the Diama Dam in Senegal.

The construction of the low dam in the 1930s and the high dam in 1960s allowed the conversion from traditional and intermittently irrigation to perennial irrigation for 300,000 ha, and resulted in increases in the prevalence of urinary schistosomiasis from less than 12% to more than 50% depending of villages and provinces. A sudden increase of intestinal schistosomiasis was also observed (Hunter et al., 1993). The Diama Dam, built in the 1980s, ought to block saltwater intrusion and create a reservoir for irrigation. Studies undertaken before the lake impoundment has shown that the condition of a potential transmission existed as intermediary snail hosts were found in fields. Two years after the dam became operational an outbreak of intestinal schistosomiasis cases was observed (Talla, et al. 1990). The same observation was made with the Selingue dam built in 1980 in Mali. Surveys undertaken by the schistosomiasis control national programme in villages around the future dam before and three years after impoundment, showed an increase in the prevalence of urinary schistosomiasis.

More recently, several papers focusing on the effects of dams and irrigation systems on parasitic diseases, concluded that there were adverse health effects (Table A1). However for all of that, the methodology used is not exempted from bias. As observations of the situation before environment changes and alterations in aquatic systems, has not been made, the authors made comparison of two zones, one with and one without agriculture irrigation. They only could observe that in the irrigated

lands zone, the prevalence of schistosomiasis (Dossou-Yovo *et al.* 1994; de Clercq *et al.*, 2000; Hunter, 2003; Dolo *et al.*, 2004; Yi-Xin and Manderson, 2005), or malaria (Ghebreyesus *et al.*, 1999; Marrama *et al.* 2004; Mutero, Kabutha *et al.*, 2004; Mutero, N'ganga *et al.*, 2004) is higher than in the non irrigated ones. However for Yapi *et al.* (2005), irrigated rice cultivation did not increase schistosomiasis risk in the forest zone while it did in the savannah zone.

Studying the causes of malaria resurgence in Azerbaijan, Temel *et al.* (2004) use an approach based on a linear regression analysis and geographical information system. They found that irrigation water use, but also soil salinity, are determinants of malaria cases.

The conclusions of negative consequences of irrigated lands on malaria transmission or prevalence are less evident for some authors. Roberts *et al.* (1992) found that in the Benoue valley (Cameroon), the anopheline density is high in irrigated rice-fields and in the neighborhood; they consider that the effect of irrigation on malaria transmission is much less important than what would be expected. Investigations on schistosomiasis and malaria transmission were completed just before the construction of the dam and the transformation of the environment in the Three Gorges Project (China). It was concluded that schistosomiasis and malaria, were not prevalent in the Three Gorges area and therefore did not constitute significant risks to the reservoir site (Gu *et al.*, 1988, cited by Hunter, 1993). But recommendations were that field studies and surveillance of transmission were necessary. In 2002, Zhen *et al.* (2005) conducted field surveys and ecological experiments in line with those recommendations. Data on human and animal prevalence status and snail habitats were collected. Positive and negative impacts were observed depending of the ecology and floods. Less important floods and the exploitation of beach along the Yangtze River contributed to decrease snail habitats. On the contrary, the flushed beaches and migratory settlements at certain altitude may become snail habitats contributed to consider the reservoir area as a potential transmission area of schistosomiasis. No drastic increase was observed in human prevalence between the two field surveys periods. Recommendations are the same as those made at the end of 1980s (Hunter, 1993), and concern surveillance that should be maintained and effort that must be made to decrease the negative impact.

- No health effects of water resources development

Klinkenberg *et al.* (2004) investigating the malaria pattern over time and space in Sri Lanka, studied the role of irrigation canals and natural streams on malaria transmission. Using a multivariate statistical analysis, they found that irrigated rice cultivation areas had a lower risk of malaria than non-irrigated areas. They explained this result by the role of socio-economic factors: due to irrigation development, the higher economic level allowed households to invest in health and in wealth-being. In the same vein, de Plaen *et al.* (2004), Audibert *et al.* (2003b), Henry *et al.* (2003), Henry *et al.* (2007) showed that irrigation systems, both in savannah and forest areas of Cote d'Ivoire, had no effect on malaria transmission. In Mali, Sissoko *et al.* (2004) showed that rice cultivation in the semi-arid sub-Saharan environment altered the transmission pattern from seasonal to perennial, but reduced annual incidence more than two-fold.

If those studies suffer from the same methodological bias that studies that found adverse health effects of dams and irrigation systems (as they compare irrigated areas and non irrigated areas once dam, reservoir, or irrigation systems were built), studies using impact analysis approach were found. Audibert *et al.* (1983, 1990) undertook a six-year monitoring of a project of irrigated rice lands in the North Cameroon (the SEMRY project). They observed the sanitary and economic situation before and after the impoundment of the reservoir lake and the settlement of the irrigation scheme on both the future irrigated area and the non-irrigated or control area. Prevalence of schistosomiasis and malaria were observed through epidemiological and malacological field surveys. The authors established that as the creation of the lake, and the development of the rice-producing scheme, had not contributed to increase the transmission of malaria or schistosomiasis which remained constant over the six years.

In India, Sharma et al. (2008) also lead a five-year study conducted during and after the construction of a small dam in malaria endemic village. A survey was also conducted in a control village. A gradual decline in malaria incidence among children was observed in the dam site village while in the control area, malaria incidence increased during the corresponding period.

Those examples caution against systematically extrapolating results from specific situations to non comparable situations. And beyond a criticism of the methodology when impact analysis is not used, lessons and useful recommendations for policy could be drawn from those field surveys, as we will see in section IV.

3.2 – Health risks associated with intensive insecticides and pesticides use: respiratory and parasitic diseases

If the use of pesticides has been one element of the Green revolution which was the origin of Asian success, pest mismanagement should have effects on agriculture sustainability. In fact, there exists a conflict between immediate benefits from intensive agricultural systems and long term negative effects either on the environment or on health: soil degradation in areas where soils are known to be fragile (Atis, 2006; van der Velde, Green, Vanclosster and Clothier, 2006), ground water pollution (Reddy and Behera, 2006; Zhen, Zoebisch, Chen and Feng, 2006), specific diseases appearance (Pretty, Morison and Hine, 2003). In the same way, insecticides are necessary to increase production but their consumption must be controlled. On one hand, fertilizers, insecticides and pesticides are all required inputs for high agriculture productivity. High agriculture productivity is a step towards hunger disappearance. On the other hand, a mismanagement of those inputs may have negative effects on health (and on environment and sustainability, de Souza Filho, Young and Burton, 1998).

The effect of agriculture inputs overuse or mismanagement on health occurs through at least two channels.

- The first one is direct as prolonged exposure to pesticides can cause chronic diseases such as cardiopulmonary or neurological problems (Dasgupta, Meisner and Huq, 2004). Studying the effects of pesticide use among smallholder cotton growers in Zimbabwe, Maumba and Swintonb (2003) found that acute pesticide symptoms were determined in large part by pesticide use practices, notably the lack of protective clothing. And if mismanagement of pesticides induces a risk for health, it also induces a cost, both financial and economic. They showed through a field survey of 280 smallholder cotton growers in Zimbabwe that acute symptoms induced direct (healthcare expenses) and indirect (time spent recuperating from illness during the growing season) costs. These costs are equivalent to 45% and 83% of annual household pesticide expenditures in the two surveyed districts. Economic benefits (due to land productivity increase) of pesticides use should then be balanced by financial costs increase (due to adverse health effects).

- The second effect is indirect and twofold. Uncontrolled pesticides use may introduce parasite resistance to insecticides. Several studies have reported severe cotton production decreases in Central American countries or in Thailand. They were attributable to insecticide over consumptions which have developed insects' resistances (Mc Caffery, 1998; Kranthi et al. 2002). They also have indirect effects on health in areas of endemic malaria. While this resistance extends to the malaria vectors (anopheles), the vector control is made more difficult (Diabate *et al.*, 2002; CREC/IRD/ London School, 2007).

So mismanagement of insecticides and pesticides use should have, as seen above, several adverse effects:

- on cost-effective agriculture policy adopted (when the costs of health deterioration exceed the economic benefits of land productivity);
- on public health i) due to the appearance of insecticide resistance which is a brake on vector control; ii) due to human exposure by unsafe manipulation of pesticides increasing skin or pulmonary diseases;

- on environment and then sustainability of agriculture when pest mismanagement induces water pollution, soil degradation.

However, here again, some voices arise in order to show the numerous benefits of pesticides use. In their paper, Cooper and Dobson (2007) plead in favour of pesticides or at least proposed a more balanced view. Through a literature survey, they can enumerate:

- i) some primary benefits (26) such as crop and livestock yields increase, food safety improvement, quality of life;
- ii) and secondary longer term benefits (31) such as increase in children's education increase or in medical care access, leading to a healthier and better educated population.

The main criticism we could make to the paper of Cooper and Dobson is that the benefits are more presented as an enumerated list rather than evaluated. The given reason is that the consequences of the effects have not manifested themselves yet. But its main interest is that they place the question of the agriculture development into a holistic approach and a societal point of view.

IV – Policy response

The high population growth rates observed after the 1950s in developing countries of Latin America and Africa, allowed the development of the agricultural sector. While the green revolution with the introduction of HYVs and irrigation systems has been a success in Asia, it was not truly the case in Africa, nor in Latin America. Despite the development of dam building (for water storage) and irrigation projects in those continents, per capita agricultural production has increased in Asia, but remained stable in Latin America and declined in Africa (Hunter et al. 1993).

However, as seen above, the construction of dams, formation of reservoirs and irrigation systems could cause health degradation as health risks. For that reason, the adoption of water resources development was largely criticized in the literature of the seventies.

After a decline, the interest around intensive agriculture and health risks again increases. A meeting, held in 22 September in New-York, created a steering group which made some recommendations as a call to action. It underlined the need for focused investments in agriculture, in order to launch a green revolution in Africa, as well education, health and infrastructure that are critical to present and future efforts to reach the MDGs.

As summarized by Hawkes and Lee (2001) in a conceptual framework drawn upon a review of the literature, links between health and agriculture lie in:

- The agriculture supply chain such as types of producers (farmers or workers), agricultural systems (intensive including irrigation, fertilizers, pesticides uses; extensive including slash, burn-clearing) and agriculture outputs (quantity, quality, prices);
- Intermediary processes such as labour process, environmental change (water, air, soil), access to food, water, land;
- Health outcomes such as occupational health risks, water and vector-borne diseases, under nutrition and chronic diseases.

Illustrating those links, Figure 6 calls two questions:

- How to increase farm productivity?
- How to cope with health risks?

Insert Figure 6

4.1 – How to increase farm productivity in Africa?

Incentives for adopting irrigation schemes and fertilizer use in African agriculture sector have not been really different from incentives in Asia. Low farm crop prices relatively to the cost of inputs should have been pivotal (<http://www.fao.org/docrep/003/X8827F/x8827f00.HTM>).

Beyond the aspect of financial incentives, which could be developed by better access to credit, the sustainability of agriculture but also farmers health require to adopt better practices in fertilizers and pests use and in water resources management.

The above review of the literature clearly showed that innovations such as irrigation systems and pests use played a huge role in increasing agricultural productivity and in the fight against poverty. The question of how to increase agricultural productivity in Africa is then asked. But, while judicious use of modern technologies is essential for efficient food production, inappropriate uses, such as excessive application rates or imbalances in input combinations, result in serious environmental problems and food safety concerns (Nyberg, 2000).

- How to induce farmers to adopt high yield innovation?

The Malawi experience is often cited as a success story that thanks to government subsidies, smallholder farmers increased land cultivated (<http://www.ipsnouvelles.be/news.php?idnews=9913>). Giné and Yang (2004) analysed the Malawi experience where 97% of households were engaged in maize production, but only 58% use hybrid maize varieties. They studied the link between insurance and the adoption of credit. It was argued that technology adoption may be hindered when returns are risky and insurance or other financial markets are imperfect (Giné and Yang, 2008). The question was whether production risk suppressed the demand for credit. For the lender, weather insurance is likely to be an attractive way to mitigate default risk and thus, it can become an effective risk management tool with the potential of increasing access to credit in agriculture at lower prices. To check this assertion, they implemented a randomized field experiment to ask whether provision of insurance against a major source of production risk induces farmers to take out loans to adopt a new crop technology. Two groups of farmers were formed. One group was offered credit for purchasing high-yield hybrid variety of maize and groundnut. The second group was offered credit plus a weather insurance policy that partially or fully forgave the loan in the event of poor rainfall. They found that if the access to credit allowed smallholder farmers to adopt a better technology, the package credit plus weather insurance did not increase the demand for loan. Conclusion is that increasing the access to credit by microfinance institutions can help farmers to purchase agriculture inputs and adopt higher technology innovation.

- Adverse effect of high agriculture technology, example of China

In the 1960s, the main problem of China was food security. Until the 1980s, the government increased the financing devoted to agricultural research. During this period, high-yielding and hybrid rice varieties and drought and pest resistance wheat varieties were developed and adopted by farmers (Nyberg, 2002).

Irrigation has played a critical role in establishing the highly productive agronomic systems. The proportion of cultivated area under irrigation increased from 18 percent in 1952 to a level at which about half of all cultivated land had been irrigated after the early 1990s. Despite a decline of interest in research in agriculture, and a breakdown of the irrigation extension systems, farmers continued to adopt new varieties produced by researchers. During the 1980s and 1990s China's producers were replacing varieties from about 20 to 25 percent of their sown areas during each cropping season. In other words, about every four to five years, China's farmers are completely turning over their technology portfolios (Nyberg, 2002). The work of Jin *et al.* (2002) confirms also that innovation and technology are the most important source of TFP growth.

However, rising demand for domestic and industrial water uses poses a serious constraint to irrigated agriculture and increasing water scarcity is being viewed as a major challenge to future food security and the well-being of people especially in the northern region of China. A balanced water management should be an answer to this constraint. For example, Wang *et al.* (2005) showed that the water management reform has been helping to increase the efficiency of water use in North China, although the scope for such reform in the long term is somewhat limited.

The agriculture sector in China recently faces a problem of environmental degradation. China is the world's leader in both chemical fertilizer and pesticide consumption (Huang, Yang, Rozelle, 2006). We saw that intensive fertilizer and pesticide use can have several adverse effects and concerns about contamination of farm produce and endangering people health.

- How to induce smallholder farmers to more effectively use intensive agriculture: the example of irrigation in the Philippines

Water control and distribution in irrigation systems for crop cultivation is usually ensured by the government as well as the maintenance of canal systems. This maintenance is not systematically done. It is well-known that poor maintenance of existing canals leads to increased amounts of lost water (Schoengold and Zilberman, 2004).

In Philippines, irrigation associations have been created. Bandyopadhyay, Shyamsundar and Xie (2007) have examined the capacity of those associations to lead operations and maintenance activities when management transfer occurs. Their hypothesis is that management transfer leads to local control and improves system performance. Using data from a survey of 1,020 farm households, their investigation underlined three interesting results:

- i) system irrigation maintenance increases with the presence of irrigation management transfer (IMT);
- ii) irrigation management transfer increases local control over water delivery which significantly increases farm yields and then rice production;
- iii) if the farmer is more certain about water delivery (thanks to IMT), this may affect his or her decisions related to other input use which is in relation to better yield;
- iv) IMT contributed to a better resolution of conflicts related to illegal use and to more cost-effective water use.

4.2 – How to cope with intensive agriculture's adverse health effect?

Water resources development may induce the development or the expansion of water borne diseases. But this risk could drastically be reduced or remain inexistent with appropriate actions. They are:

- **Environmental sanitation and health education**

A control of schistosomiasis due to *S. mansoni* was launched in November 1960 in a Brazilian village. Control measures were limited to environmental sanitation and a community health education programme. A seven-year monitoring survey showed that human infection rates were progressively reduced in the project area. Eight years after the beginning of the project, field surveys showed that a successful degree of control of schistosomiasis has been achieved in the project area (Barbosa, Pinto and Souza, 1971).

- **Modifying or manipulating the environment (MME)**

In the case of irrigated lands, management opportunities appear for controlling vector-borne diseases and at the same time improving the water efficiency and then saving cost irrigation (Schoengold and Zilberman, 2004).

Several examples of the positive effect of those opportunities are showed with the SEMRY project, developed in the 1979s in North Cameroon (Audibert, 1983, Audibert 1990), with the malaria and schistosomiasis control projects in the Sichuan (Liu *et al.* 2004), with malaria control in India (Tyagi, 2004).

The SEMRY project has, since the beginning, been considered by the management team and the donors (the French Foreign Affairs Ministry, the World Bank, and the Government of Cameroon) as a development project. This point of view conducted to lead this project through a multisectoral approach. If the general goal of the project was to increase the national rice production, specific goals were to improve farmers' income and households' wealth-being. With the creation of a lake, the settlement of farmers around the future irrigated lands, several activities were undertaken which resulted to keep low health risks (Audibert, 1983, Audibert 1990). The adopted strategies were:

- to cement the primary irrigation canal and undertake systematic maintenance of secondary canals and drains;
- to supply safe domestic water and to improve sanitation by boring wells and building latrines in the new settled villages;
- to improve health supply by building health facilities and developing health education.

The consequence of those strategies was that the prevalence and the incidence of the two main water borne diseases, schistosomiasis and malaria, remained stable and low in the project area.

Prior to the mid-1960s, malaria in the Sichuan Province was a major public health problem, with the fourth highest level of morbidity in the country (Liu *et al.*, 2004). Over the last three decades, the irrigation network has been gradually extended thus ensuring water security and increasing the area of arable land. Land was farmed by intermittent wet/dry irrigation and rice fields that had been left flooded but fallow throughout the winter are now under an annual cycle of wet crop/dry crop rotation to maximise productivity. Between 1950 and 1960, an integrated malaria control programme approach (cases detection, treatment, indoor-spraying) was established. It contributed to a drastic decrease in malaria severity⁶ despite the expansion of irrigated lands, where farmers have traditionally kept flooded all year round to ensure an adequate water supply. Field studies showed that the vector breeding has been greatly reduced. It would appear that vector populations have now fallen below the level required to sustain malaria transmission (Liu *et al.*, 2004).

In the same province, the World Bank has a project on schistosomiasis control. Early efforts focused on the control of the intermediate host snails by chemical molluscicides and environmental management. Large-scale community participation was a central feature in environmental management. In the 1990s, morbidity control was done through the administration of Praziquantel, which had been introduced for large-scale use in the previous decade, coupled with health education. The transmission of schistosomiasis has considerably decreased and is now very low. The strategy adopted was (Wang, Utzinger and Zhou, 2008):

- i) Improvement of the mechanisation of agriculture, by replacing buffaloes with tractors (in order to achieve the elimination of the animal disease);
- ii) Installation of sanitation facilities in houses;
- iii) Provision of toilets for mobile populations.

Tyagi (2004), in a review of the literature between 1930 and 2000, explained the resurgence of malaria in the Tar desert (India) by the mismanagement of irrigation systems. The main incriminated factors are:

- Cessation of flow due to heavy sedimentation and profuse growth of hydrophytic plants;
- Excessive peeling-off of the canal lining allowing water percolation through embankments;
- Vast collections of seepage water along the main canal.

For this author, parasitic diseases could be controlled by using meticulously practised wet and dry irrigation technologies.

⁶ The number of cases was reduced to 10-20 cases/10,000 people.

After a systematic literature review between 1900 and now, on 40 studies examining the effect of environmental management on malaria, Keiser, Singer and Utzinger (2005) reached the same conclusion. Modifying or manipulating the environment could create unfavourable conditions for vector propagation, reduce vector habitats and contribute then to reduce malaria burden.

In conclusion, modifying or manipulating the environment creates unfavourable conditions for vector propagation and reducing vector habitats. It consists of (Prüss-Ustün, Bos, Gore, Bartram, 2008; Dodd and Cassels, 2006; Schoengold and Zilberman, 2004; Tyagi, 2004; Audibert *et al.*1990):

- reducing vector habitat through infrastructure: drainage, systematic maintenance, levelling land, contouring reservoirs, modifying river boundaries;
- alternate wetting and drying of irrigated paddy fields, synchronization of paddy fields, alternate periodic flushing of natural and human-made waterways;
- introducing predators, such as larvivorous fish;
- improving access to safe water and good sanitation conditions;
- promoting health education.

▪ **Integrated pest management (IPM)**

Dasgupta, Meisner and Huq (2004) studied the health and environment effects of overusing pesticides among farmers in Bangladesh. A survey of smallholder farmers was carried out and showed that 47% of farmers use more than the recommended doses of pesticides. The authors observed that a prolonged exposure to pesticides could cause chronic diseases such as cardiopulmonary or neurological problems (26% of farmers experienced multiple health problems).

While fertilizers, insecticides and pesticides should be used with caution, farmers misunderstood pesticide health hazards, and so did little to protect themselves. Maumba and Swintonb (2003) found that using simple colour codes for indicating the different degrees of pesticides toxicity is not enough. For those authors, a better farmer education in pesticides exposure and the integrated pest management are needed. Integrated pest management (IPM) allows farmers to producing crops in a cost-effective and sustainable manner helping them to suppress pests by using non-chemical methods.

▪ **Integrated Vector Management (IVM)**

Water resources development plays an important role in farm productivity and consequently in Africa economic development. But, expansion of irrigation systems and irrigated land are not free of health risks. Intensifying pesticides and insecticides use is also important for the development of agriculture. On the other side, insecticides play an important role in the prevention and the control of parasitic diseases in Africa endemic countries. Households use insecticides in order to protect themselves against nuisance vector and disease. They also use pesticides for controlling pest or unwanted species of plant causing harm during the production process. Public professionals through ministry of health or ministry of agriculture, but also private professionals, use pesticides and insecticides for different objectives. A conflict may arise between insecticides used for public health and insecticides used for agriculture development (Figure 6). The integrated vector management (IVM) approach could reconcile both public health and agriculture development objectives. IVM is a decision-making process for the management (<http://www.who.int/malaria/integratedvectormanagement.html>) of:

- i) vector populations, so as to reduce or interrupt transmission of vector-borne diseases;
- ii) pest use, so as to reduce health risks and soil and water degradation

Its characteristic features include:

- Selection of methods based on knowledge of local vector biology, disease transmission and morbidity;
- Collaboration within the health sector and with other public and private sectors that impact on vector breeding;
- Engagement with local communities and other stakeholders;
- A public health regulatory and legislative framework;
- Rational use of insecticides;
- Good management practices.

Conclusion

The role of the agriculture on the economic development is well recognized. Increasing agriculture productivity needs to adopt innovation and intensive technology such as irrigation system production, fertilizers, insecticides and pest use. A misuse or mismanagement of those technologies could induce health problems.

However, several activities blocking the development or the occurrence of parasitic diseases and other health problems could be undertaken. They include:

- Integrated pest management;
- Integrated vector management;
- Modification and manipulation of the environment,
- Improvement of sanitation conditions;
- Health education;
- Education on good practices.

Those actions cannot be effective without a multisectoral commitment and an intersectoral negotiation.

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Table 1: Importance of agriculture in some African countries

Country	Year	Agriculture value added (constant prices, 2000\$ millions)				Agriculture average annual growth %			GDP average annual growth %		
		1980	1990	2000	2005 ^a	1980-89	1990-99	2000-05	1980-89	1990-99	2000-05
Benin		316	467	824	1,028	5.2	5.8	4.6	3,1	4,5	4,2
Bostwana		132	155	139	130	1.8	-0.9	-1.1	11,5	6,1	5,9
Burkina Faso		410	531	881	919	3.6	4.3	2.1	3,6	3,8	5
Cameroon		1,023	1,298	2,062	2,460	2.5	5.3	3.7	4	0,4	3,7
Central African Republic		298	332	478	547	1.7	3.6	3.6	0,9	1,3	-0,2
Chad		306	321	563	694	3.1	5.5	3.1	5,4	2,2	12,7
Congo, Democratic Republic		1,565	2,011	2,126	2,150	2.5	2.2	0.4	1,8	-5,5	2,2
Côte d'Ivoire		1,628	1,756	2,400	2,438	-0.4	3.2	0.5	-0,2	2,6	-0,9
Ghana		1,226	1,268	1,756	2,221	0.9	3.3	5.0	2	4,3	4,8
Kenya		2,192	3,138	3,649	4,377	3.2	1.8	2.8	4,2	2,2	3,1
Mali		656	792	938	1,214	2.6	3.1	4.9	0,6	3,6	5,9
Namibia		179	223	338	354	1.3	3.5	1.6	1,1	4,1	4,4
Rwanda		535	558	750	951	0.8	1.5	4.3	3,2	2,1	5,5
Senegal		506	602	791	843	2.5	2.1	1.1	2,7	2,7	4,4
Tanzania		...	2,767	3,773	4,834	...	3.2	5.0	3,8	3,1	6,3
Togo		220	342	455	524	5.7	4.5	2.8	2,6	2,6	1,7
Uganda		...	1,401	2,014	2,481	1.5	3.6	4.1	3	6,9	5,6
Algeria		2459	3246	4600	6469	4,3	4,0	7,3	2,8	1,6	4,5
Morocco		4094	5925	4610	6147	7,00	0,1	6,9	3,9	2,7	3,7

^aProvisional. *Source*: World Bank, 2008.

Table 2: Importance of agriculture in some African economies

Country	Year	Structure of merchandise exports (% of total exports), 2000-05		Top one export, 2005		Irrigated land (% of cropland) 2001-03	Malaria 2000-05 Deaths due to malaria (per 100,000 people)	Malnutrition 2000-05 (% of children under age 5 stunting)
		Agricultural raw materials	Food	product	share of total exports			
Benin		61	24.8	cotton	55,3	0.4	177	30.7
Bostwana		0.1	2.4	diamonds	88,2	0.4	15	23.1
Burkina Faso		72.3	16.4	cotton	84,5	0.5	292	38.7
Cameroon		13	17.1	Crude petroleum	48,8	0.4	108	31.7
Central African Republic		41.2	0.8	diamonds	40	0.1	137	38.9
Chad		...		crude petroleum	94,9	0.8	207	40.9
Congo, Democratic Republic		...		diamonds	42,6	0.1	224	38.1
Côte d'Ivoire		9.2	55.8	cocoa beans	38,2	1.1	76	...
Ghana		5	77.1	cocoa beans	46,1	0.5	70	29.9
Kenya		12	39.7	tea	16,8	2.0	63	30.3
Mali		22.3	9.6	cotton	81,8	4.9	454	38.2
Namibia		1.3	48.3	diamonds	39,1	1.0	52	23.6
Rwanda		7.3	52.3	coffee	51,9	0.6	200	45.3
Senegal		2.1	28.8	inorganic acid	38,8	4.8	72	25.4
Tanzania		16.7	56.7	gold	10,9	3.6	130	37.7
Togo		8.9	21.5	cocoa beans	22,4	0.3	47	...
Uganda		11.6	64	coffee	31,1	0.1	152	39.1
Algeria		0.0	0.2	crude petroleum	67,2	6.9	...	19.1
Morocco		1.9	21.5	Inorganic acid	7,2	15.4	...	18.1

Source: World Bank, 2008, Tables 6.1, 6.2, 8.2

Annex

Table A1: Agriculture and endemic diseases: a partial synthesis

Author(s), Year	Area covered, Objective, Method,	Type of agricultural activity	Health, Disease variable	Conclusion, observations
Adverse health effects of intensive agriculture				
Hunter, J.M., 2003	<p>Areas covered: Rural Ghana, five districts (1959-1997)</p> <p>Objective of the study: To investigate the long-term health consequences of an agricultural development project (dams) and assess the longevity of a disease impact of the original project</p> <p>Method: Surveys and comparison between areas with agricultural dams and areas without.</p>	Agricultural dams	Number of cases of <i>Schistosomiasis hematobium</i> among population	Four decades later, the prevalence of <i>hematuria</i> (bloody urine) is still abnormally higher in the regions where dams have been constructed, even though many of them are in a neglected state.
Muteru, C.M., Kabutha, C., Kimani, V., Kabuage, L., Gitau, G., Ssenyonga, J., Githure, J., Muthami, L., Kaida, A., Musyoka, L., Kiarie, E., Oganda, M., 2004	<p>Areas covered: Mwea Division, Kenya</p> <p>Objective of the study:</p> <ul style="list-style-type: none"> - To document an application of the ecosystem approach to malaria research in Kenya; - To present results on the biophysical and social environments influencing malaria prevalence in villages with and without rice irrigation; - To propose phased actions with potential to facilitate long term solutions to malaria on the basis of agroecosystem management and improved utilization of local resources. <p>Method: 5 phases of the study:</p> <ul style="list-style-type: none"> - Stakeholder consultation and existing area 	Rice farms' irrigation	<ul style="list-style-type: none"> - Number of <i>Anopheles arabiensis</i>, - Prevalence of malaria 	Results of the entomological evaluation showed a 30–300-fold increase in the number of the local malaria vector, <i>Anopheles arabiensis</i> , in villages with rice irrigation compared to those without irrigation yet malaria prevalence was significantly lower in these villages (0–9% versus 17–54%). The prevalence of malaria in Mwea Division was higher in villages located outside the rice irrigation scheme compared to those inside. One of the explanations of this “paddies paradox” is on the basis of differences between the ecological

	<p>health care utilization data collection.</p> <ul style="list-style-type: none"> - Participatory needs assessment at the village level. - Household and farmer surveys. - Entomological and parasitological evaluation. 			<p>and socio-economic environments inside and outside irrigation schemes.</p> <p>Malaria is related to rice cultivation and presence of cattle in Mwea.</p>
de Clercq D; Vercruyssen J; Sene M; Seck I; Sall CS, 2000	<p>Areas covered: <i>First survey in</i> Middle and Upper Valleys of the Senegal River basin. 1445 children aged 7-14 years: 1011 in 10 villages near Matam, and 434 in 4 villages near Bakel Second survey in in June 1999, on 755 children from 9 of the study villages near Matam</p> <p>Objective of the study: Investigate the importance of the increase in irrigated land on the perimeters of the Middle and Upper Valleys of the Senegal River basin on the prevalence and intensity of urinary schistosomiasis.</p> <p>Method: Surveys and statistical analysis</p>	Rice farms' irrigation	Prevalence and intensity of urinary schistosomiasis	<p>Significant increases in the prevalences of both micro- and macro-haematuria in three of the villages, all of which were adjacent to the Senegal River and practicing irrigated agriculture. None of the other study villages re-surveyed was irrigating any of its agricultural land.</p>
Temel, T., 2004	<p>Area covered: Azerbaijan (58 districts)</p> <p>Objectives of the study: Investigate the causes of malaria resurgence in Azerbaijan</p> <p>Method: Linear regression analysis and GIS (geographical information system)</p>	<p>Agricultural variables included in the regression among other covariates:</p> <ul style="list-style-type: none"> - Number of formerly state-owned farms - Number of formerly collective farms - Area of irrigated land - Area of agricultural land with severe salinity - Area of eroded land 	Malaria prevalence: the ratio of the number of malaria cases to the population size	<p>Among agricultural variables, only irrigation water use and soil salinity are significant determinants of the number of malaria cases in population. The other determinant of malaria prevalence in Azerbaijan is longitude, a geographical variable.</p>
Robert, V., van den Broek, A., Stevens, P., Slootweg, R., Petrarca, V., Coluzzi, M., Le Goff, G., Di Decod, M.A., Carnevale P., 1992	<p>Area covered: Benoue Valley, northern Cameroon</p> <p>Objectives of the study: Study the impact of the increase of irrigation in the Benoue Valley of malaria</p>	Irrigated area under cultivation	<ul style="list-style-type: none"> - Number of indoor resting mosquitoes caught by Pyrethrum spray - Biting rate of 	<p>The anopheline density is high in irrigated rice-fields and in the neighborhood. However, an analysis of the sources of the blood meals provides evidence for indoor</p>

	transmission.		mosquitoes (number of bites per man per night) - Source of the blood meal (human or nonhuman)	resting after feeding on cattle outside. So the effect on malaria transmission is much less important than what would be expected.
Chimbari, M.J., Chirebvu, E., Ndlela, B., 2004	Area covered: Mashonaland East Province of Zimbabwe Objective of the study: To undertake a comparative assessment of the malaria and schistosomiasis risks associated with surface and sprinkler irrigation systems in Zimbabwe	Surface and sprinkler irrigation	- Number of malaria cases (based on clinical symptoms and thereafter confirmed by microscopic tests) - Number of schistosomiasis cases (based on clinical symptoms)	The risk of contracting malaria was greater in sprinkler schemes than in surface schemes. In contrast, the risk of contracting schistosomiasis was indicated to be greater in surface schemes than in sprinkler schemes.
Dolo, G., Briët O.J.T., Daoa, A., Traoré S.F., Bouaré, M., Sogoba, N., Niaré, O., Bagayogo, M., Sangaré, D., Teuscher, T., Touré, Y.T., 2004.	Area covered: Sahel of Mali (office du Niger around the town of Niono) Objective of the study: To study whether the extended breeding season and increased mosquito populations caused by irrigated rice cultivation have effects on malaria transmission, as compared to the non-irrigated Sahel Method: Cross-sectional entomological surveys in three irrigated and three non-irrigated villages	Irrigation scheme for rice cultivation	- Number of mosquitoes caught - Number of anopheles <i>gambiae</i> (malaria vector) among the mosquitoes caught	Rice cultivation in the Sahel environment altered the transmission patterns from seasonal to perennial.
Dossou-yovo, J., Doannio, J., Rivière, F., Duval, J., 1994.	Area covered: Bouaké city (Côte d'Ivoire) Objectives of the study: To investigate the impact of development of rice-fields in Bouaké city (Côte d'Ivoire) on anopheline populations and malaria transmission. Method: Comparison of districts of the city where low-lying areas are used for rice-fields (with irrigation) with those used for market	Rice-fields irrigated	- Total number of mosquitoes caught - Species of mosquitoes caught (anophelines and culicines) - Biting rate - Malaria transmission rate (number of infective bites)	In rice-field districts, <i>A. gambiae</i> densities are particularly high but sporozoite index are low. But in Bouaké city, because the annual average biting rate is high, the infective bites are important in the year, resulting in a higher malaria transmission risk.

	gardening (without irrigation).			
Ghebreyesus, T.A., Haile, M., Witten, K.H., Getachew, A., Yohannes, A.M., Yohannes, M., Teklehaimanot, H.D., Lindsay, S.W., Byass, P., 1999.	<p>Area covered: Tigray region (northern Ethiopia)</p> <p>Objective of the study: To assess the impact of construction of micro-dams on the incidence of malaria in nearby communities in terms of possibly increasing peak incidence and prolonging transmission.</p> <p>Method: Comparison between children in at risk and control villages</p>	Presence of micro-dams close to villages	Incidence of malaria (with 95% confidence intervals) among children under 10 years	Overall incidence of malaria for the villages close to dams was 14.0 episodes/1000 child months at risk compared with 1.9 in the control villages—a sevenfold ratio.
Marrama, L., Jambou, R., Rakotoarivony, I., Leong Pock Tsi, J.M., Duchemine, J.B., Laventure, S., Mouchet, J., Roux, J., 2004	<p>Area covered: Three villages in Southern Madagascar</p> <p>Objectives of the study:</p> <ul style="list-style-type: none"> - To identify malaria vectors, - To evaluate the transmission and - To compare the influence of irrigation in three different ecosystems (natural sub-arid area, irrigated sub-arid area and irrigated humid area). <p>Method: Surveys and statistical analysis</p>	Three dummies: - Natural sub-arid area, - Irrigated sub-arid area - Irrigated humid area	<ul style="list-style-type: none"> - Number of mosquitoes caught - Distribution of species - Blood feeding - Number of infective bites 	In the irrigated scheme of the sub-arid region, malaria transmission was 150 times higher than in the natural ecosystem and <i>Anophele funestus</i> was the main vector, responsible for 90% of infective bites. In the irrigated scheme of the humid region, the level of malaria transmission was high and 2/3 of the infective bites were due to <i>A. mascarensis</i> .
Mutero, C.M., Ngang'a, P.N., Wekoyela, P., Githure, J., Konradsen, F., 2004	<p>Area covered: Mwea rice irrigation scheme, central Kenya</p> <p>Objectives of the study: to study the effect of ammonium sulphate fertiliser) on mosquito larval populations in rice fields</p> <p>Method: Experiment with complete randomised block design and statistical analysis</p>	<ul style="list-style-type: none"> - Ponds (irrigated) treated with ammonium sulphate fertiliser. - Control group of pond non treated 	<ul style="list-style-type: none"> - Larval populations of <i>Anophele arabiensis</i> - Number of culicine mosquitoes 	Ammonium sulphate fertiliser reduces turbidity of water in rice fields, thereby making them visually more attractive for egg-laying by <i>Anophele arabiensis</i> and culicine mosquitoes.
Yi-Xin, H., Manderson. L., 2005.	<p>Area covered: China</p> <p>Objectives of the study: To explore some of the social and contextual factors that influence the epidemiology of <i>Schistosomiasis japonica</i>.</p>	- Rice fields areas and livestock breeding (included among other economic factors such as occupation, and wealth and income).	Prevalence of <i>schistosomiasis japonica</i> .	Many factors are responsible for <i>schistosomiasis japonica</i> infection in China population. Among farmers, human infection is significantly related to agricultural production in rice fields infested

	<p>Method: Econometric model with policy environment, economic factors, domestic environment and socio-demographic factors as explanatory variables of <i>schistosomiasis japonica</i> prevalence in China.</p>			with the intermediate host snail, and to rates of the infection in livestock.
No adverse health effect of intensive agriculture				
de Plaen R., Seka, M.L., Koutoua A., 2004.	<p>Area covered: Six villages in Northern Cote d'Ivoire (Kaforo, Nambekaha, Naoualakaha, Kohotiery, Fapaha, and Nongotchenekeha)</p> <p>Objective of the study: Explore the interactive role of environmental, social, economic, cultural and biological factors that generate malaria.</p> <p>Method: Data collection (through mapping of agricultural fields, questionnaires, individual (180) and group (24) semi-controlled interviews and detailed, thematic interviews with key informants), followed by statistical analysis.</p>	<p>Intensification of low-land irrigated rice cultivation. Villages are classified as: R1: villages with one harvest of lowland rice annually R2: villages with two harvests of lowland rice annually</p>	Malaria incidence and severity of malaria symptoms in children	Irrigation itself does not contribute to increased malaria transmission. But it does influence other mechanisms that impact malaria incidence and symptoms' severity, potentially by influencing children's vulnerability to the disease (women's disposable income, women's time to take care for their children). Therefore, it appears that one of the ways through which irrigation affects malaria in Northern Cote d'Ivoire is through its impact on the farming system (crop distribution and labour organization, harvest management, etc.), the socio-economic organization (distribution of roles and responsibilities within the household), and financial status of women, and through the ways such transformations affect women' capacity to react to the disease.
Audibert, 1983 ; 1990	<p>Areas covered: Rural North Cameroon, 30 villages, 1979-1985</p> <p>Objective of the study: To investigate the long-term health consequences of an agricultural</p>	Lake and irrigated land	Prevalence of urinary and intestinal schistosomiasis, Prevalence of malaria Prevalence of malnutrition	Six years after the lake was filled, and the introduction of irrigated lands, the prevalence both of schistosomiasis and malaria remained stable. No changes in the transmission sites were observed.

	<p>development project (lake and irrigated lands for rice cropping) and assess both the consequences of this project on endemic diseases and nutrition incidences and the impact of diseases on production</p> <p>Method: Impact analysis with comparison between areas with and areas without project, before and after his implementation. Epidemiological, demographic and economic surveys were led during six years, among the same villages and the same inhabitants. Increase of the population in the project area was taken in consideration by including a sample of new migrants, after the third round.</p>			<p>Malacological investigations showed a decrease in the snail population in the project area.</p> <p>Main conclusion: Contrary to what expected, dam and irrigated paddy fields has not been a risk factor for the endemic diseases, schistosomiasis and malaria. The project had undertaken some managements which contributed to control vector-borne diseases. Those managements were: - alternate wetting and drying of irrigated paddy fields, -control farming; - drain cleaning and management - well construction and proper sanitation</p>
Klinkenberg, E., van der Hoek, W., Amerasinghe, F.P., 2004	<p>Area covered: Uda Walawe region in south eastern Sri Lanka</p> <p>Objectives of the study: - To investigate the malaria pattern over time and space - To correlate this with potential risk factors within land use, socio-economic, and meteorological parameters - To explore whether an epidemic forecasting system could be developed</p> <p>Method: Multivariate statistical analysis</p>	Presence of irrigation canals, presence of natural streams	Number of malaria cases	Irrigated rice cultivation areas had a lower risk of malaria than non-irrigated areas. This difference could be due to socio-economic factors related to irrigation development and/or transmission dynamics related to vector density or species composition.
Sharma, S.K., Tyagi, P.K., Upadhyay, A.K., Haque, M.A., Adak, T., Dash. A.P. 2008.	<p>Area covered: Sundargarh District, Orissa, India</p> <p>Objectives of the study: To present results of a 5-year study</p>	Small dams in the village	Number of new malaria cases among children aged 1–5 years	There was a gradual decline in malaria incidence among children in the dam site village. In the control area, there was an increase

	<p>conducted during and after construction of a small dam in a malaria endemic village</p> <p>Method: Comparison between study and control villages</p>			<p>in malaria incidence during the corresponding period and the incidence had nearly doubled by 2004. The apparent decline in malaria incidence among children of 1–5 years age group in the village with the dam and the difference in incidence rate in this and the control villages was statistically significant ($P < 0.01$).</p>
<p>Sissoko, M.S., Dicko, A. Tavai Briët, O.J., Sissoko, M., Sagara, I., Keita, H.D., Sogoba, M., Rogier, C., Touré, Y.T., Doumbo O.K., 2004.</p>	<p>Area covered: District of Niono, Sahelian Mali</p> <p>Objectives of the study: To examine whether irrigated rice farming in the Sahel alters the dynamic and magnitude of malaria infection and morbidity</p> <p>Method: Comparison of malaria transmission patterns between irrigated and non-irrigated villages</p>	<p>- Three villages in the irrigated perimeter that practice double rice cropping.</p> <p>- Three villages from outside the irrigated perimeter</p>	<p>Number of malaria cases among children of 0–14 years of age</p>	<p>Rice cultivation in the semi-arid sub-Saharan environment altered the transmission pattern from seasonal to perennial, but reduced annual incidence more than two-fold.</p>
<p>Zheng J., Gu, X., Xu, Y., Ge, J., Yang, X., He, C., Tang, C., Cai, K., Jiang, Q., Liang, Y., Wang, T., Xu, X., Zhong, J., Yuan, H., Zhou, X., 2002.</p>	<p>Area covered: Yangtze River area (China)</p> <p>Objectives of the study: To determine the relationship between the changes of environment and the transmission of <i>Schistosomiasis japonica</i> after the construction of the Three Gorge Reservoir, based on the predictive studies on the changes of water level and sediment of silts.</p> <p>Method: Data collection (surveys) and analysis and ecologically intimated experiments.</p>	<p>Construction of the Three Gorge Reservoir, a huge dam project</p>	<p>Predicted Population of <i>Oncomelania</i> snails</p>	<p>The construction of the huge dam and the formation of the Three Gorge Reservoir on the Yangtze River may have both positive and negative impact on schistosomiasis transmission and control.</p> <p>- Positive impact: The way of flush and sediment in the Yangtze River will be changed after the dam construction. Snail habitats will be reduced in these sediment aggravated areas which cause harm to the development of snails.</p> <p>- Negative impact: the natural conditions of the Three Gorge Reservoir are suitable for snail development and prevalence</p>

				of schistosomiasis. It will form many beaches after the dam construction due to the decrease of velocity of water flow and the sedimentation of silts. In addition, snails may breed in the ditches surrounding migratory settlements.
Tyagi, 2004	<p>Areas covered: Thar desert in India</p> <p>Objective of the study: Studying the system of canal-based irrigated agriculture in order to understand the underlying factors responsible for the resurgence of malaria, and the possible repercussions of mismanagement of irrigation systems</p> <p>Methodology: Review of the literature from 1930 to 2000 on malaria in the area, before and after the development of irrigation crops and the built of irrigation canals</p>	<p>Extensive irrigation from three different canal systems in order to develop growing irrigation-intensive crops like paddy, groundnut, cotton, mustard, wheat and sugarcane, and to provide drinking water to the desert dwellers.</p> <p>Actually, 5500 km of distributaries already irrigate 950,000 ha of land.</p>	<p>Density of Anopheline fauna</p> <p>Prevalence and incidence of <i>P.vivax</i> and <i>P.falciparum</i></p> <p>The mismanagement of irrigation was responsible of the resurgence of malaria. It is: (1) cessation of flow due to heavy sedimentation and profuse growth of hydrophytic plants, (2) excessive peeling-off of the canal lining allowing water percolation through embankments, (3) vast collections of seepage water along the main Indira Gandhi Canal, (4) pilferage of canal water leading to short or long-term pool formations, and (5) delays in construction activity of the main canal and its distributaries resulting in stagnation of canal water for long</p>	<p>Positive association between paddy cultivation and malaria upsurge</p> <p>But, malaria in areas where irrigated lands for intensive crops were developed, could be controlled by using meticulously practised wet and dry irrigation technologies, even if water from canals is available in excess.</p>

			periods	
Keiser et al. 2005	<p>Areas covered: All countries concerned by malaria between 1900 and now</p> <p>Objective of the study: Study the effect of environmental management interventions on malaria morbidity and mortality</p> <p>Methodology Systematic literature review (or meta-analysis). 40 studies were identified that emphasised environmental management interventions and reported clinical malaria variables as outcome measures. Among those studies, 16 applied a before-and-after evaluation design (comparing the pre-programme situation with the malaria situation during or after implementation of the interventions), and seven studies (eight datasets) compared an environmental management intervention group with a control group</p>	Malaria of deep forest, as well rural malaria attributable agricultural and non-agricultural man-made activity or habitats and urban malaria	Malaria	Modifying or manipulating the environment could create unfavourable conditions for vector propagation and reduce vector habitats and contribute then to reduce malaria burden
Yapi, Y.G., Briët, O.J.T., Diabate, S., Vounatsou, P., Akodo, E., Tanner, M., Teuscher, T., 2005.	<p>Area covered: Savannah (North) and forest (West) zones of Côte d'Ivoire</p> <p>Objectives of the study: - To assess the impact of irrigated rice growing on schistosomiasis transmission in savannah and forest zones of Côte d'Ivoire - To characterize the level of prevalence and intensity of schistosomiasis infection and other helminth infections in these zones</p> <p>Method: Urine and stool sample collection followed by statistical analysis for a comparison of children in the three agroecosystems.</p>	Villages classified according to surrounding inland valleys into three agro-ecosystems in both savannah and forest zones: (R2) full or partial water control allowing two rice cycles per year; (R1) no or partial water control allowing one harvest per year (R0) absence of rice growing.	Prevalence of <i>Schistosoma mansoni</i> and <i>Schistosoma haematobium</i> among children aged between five and 15 years	In the forest zone, inland valley rice cultivation did not increase <i>schistosomiasis</i> risk; intensity of infection was not related to the amount of rice cultivation but to the amount of naturally occurring surface water. In the savannah, intestinal (<i>mansoni</i>) <i>schistosomiasis</i> was significantly more prevalent in the rice cultivating agroecosystems than in the control system, and intensity of infection was related to the amount of rice cultivation and not to the amount of naturally

				occurring surface water.
Some examples of studies focused on endemic diseases economic impact				
Audibert, 1986	<p>Areas covered: Rural North Cameroon, 40 villages, 1979-1985</p> <p>Objective of the study: To investigate the long-term health consequences of an agricultural development project (lake and irrigated lands for rice crop) and assess both the consequences of this project on endemic diseases and nutrition incidences and the impact of diseases on production</p> <p>Methodology: Impact analysis with comparison between areas with and areas without project, before and after his implementation. Epidemiological, demographic and economic surveys were led during six years, among the same villages and the same inhabitants. Increase of the population in the project area was taken in consideration by including a sample of new migrants, after the third round.</p>	Irrigated rice crop and rainy traditional crops	Prevalence of urinary and intestinal schistosomiasis, of malaria and malnutrition	Six years after the lake was filled, and the introduction of irrigated rice crops, the prevalence both of
Audibert, 2003a	<p>Areas covered: Rural Mali, 30 villages, 1989-1992</p> <p>Objective of the study:</p>			
Audibert, 2003b	<p>Areas covered: Cote d'Ivoire, 21 villages, 1989-2001</p> <p>Objective of the study:</p>			
Dasgupta, Meisner, Wheeler, 2004	<p>Areas covered: Bangladesh</p>			

	<p>Objective of the study: To compare outcomes and environment and health risks for farming with ecologically integrated pest management and conventional techniques</p> <p>Methodology: Large survey of Bangladeshi farmers (with IPM and conventional farming), using structured questionnaires</p>			
Packard, 2001	<p>Areas covered: Transvaal province, South Africa</p> <p>Objective of the study: Check the assumption that malaria was a barrier to economic development in the Transvaal lowlands prior to World War II, as fertile land would not be cultivated.</p> <p>Methodology: Historical review of literature</p>	Lowlands	Cases of malaria	<p>Show that wealthy people (such as the white rich) could protect themselves against malaria (better life conditions, availability of drugs)</p> <p>The presence of malaria in the lowveld regions of South Africa clearly created a barrier to economic development. However, the impact of malaria on agricultural production varied by race and class. The presence of malaria did not prevent the development of capital-intensive white farming.</p>
Umeh C. J., Amali, O., Umeh, E.U, 2001	<p>Area covered: Benue state, Nigeria</p> <p>Objectives of the study:</p> <ul style="list-style-type: none"> - To attempt to determine land use differences, if any, between households in Nigeria, based on their level of urinary schistosomiasis - To ascertain if land use has any effect on schistosomiasis prevalence and intensity in the study area <p>Method: Descriptive statistics and multiple regression analysis.</p>	Rural land use (surface under cultivation)	Level of infection with Schistosomiasis within HH: households are classified as low infection households (LIH) if the infection level is two standard deviations below mean intensity and heavy infection households (HIH) are defined as households with above-mean intensity.	Urinary schistosomiasis has a distortive impact on land use. Low infection households use on average more land than heavy infection households, this conclusion holds when the other determinants of land use are controlled for.
El Karim, M.A, Collins, K.J.,	Area covered:	Physiological	Moderate infection with	The energy expenditure

Dore C., 1987.	Gezira, Sudan Objectives of the study: Investigate infection with <i>Schistosomiasis mansoni</i> decreases productivity in fields Method: Examine the difference in the energy expenditure between two groups of farm workers (38 infected and 8 non-infected)	performance: Energy expenditure (as measured by Kofronyi-Michaelis respirometers) in the fields	<i>Schistosomiasis mansoni</i> (at least 500 eggs/g of faeces)	of the non-infected was higher than that of infected villagers. The corresponding relative work level in the non-infected was also higher than in the infected. However, neither of these differences was statistically significant (probably because of the small sample size).
Asare Afrane, Y., Klinkenberg, E., Drechsel, P., Owusu-Daaku, K., Garms, R., Kruppa, T., 2004	Area covered: Kumasi, Ghana Objective of the study: To verify the possible impact of irrigated urban agriculture on malaria transmission in cities. Method: Mosquito identification, households survey and statistical analysis.	Irrigation in urban areas for agriculture: Comparison between city locations without irrigated agriculture (UW), city locations with irrigated urban vegetable production (UI), and peri-urban (PU) locations with rain-fed agriculture.	- Adult anopheline densities (mosquitoes number) - Breeding sites of mosquitoes	The number of reported malaria episodes and days lost due to illness was significantly higher in UI than UW in both seasons for all age groups. Individuals living in UI lost about 0.5 (rainy season) to one (dry season) days more due to malaria than those living in city parts without agriculture during the 3 months recall period.
Girardin, O., Daoa, D., Koudou, B.G., Essé, C., Cissé, G., Yao, T., N'Goran, E.K., Tschannen, A.B., Bordmann, G., Lehmann, B., Nsabimana, C., Keiser, J., Killeen, G.F., Singer, B.H., Tanner, M., Utzinger, J., 2004.	Area covered: Tiémélékro, located in the district of Dimbokro (Central Côte d'Ivoire) Objective of the study: To assess and quantify the effect of ill health, particularly malaria, on the performance of farm activity, with an emphasis on drip-irrigated vegetable farming in rural Cote d'Ivoire. Method: Comparison of farmers classified according to the number of days prescribed sick due to malaria	Marketed yields of okra and cabbage	Number of days prescribed sick due to malaria	Negative correlations between total yield and the number of days prescribed sick due to malaria