WORKING PAPER 47

Malaria in Irrigated Agriculture

Papers and Abstracts for the SIMA Special Seminar at the ICID 18th International Congress on Irrigation and Drainage, Montreal, 23 July 2002

SIMA Document 2

Eline Boelee, Flemming Konradsen and
Wim van der Hoek, editors

International Water Management Institute

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The SIMA Document Series contains contributions from participants in the SIMA Network and is intended to stimulate discussion among people interested in malaria and agriculture. The views expressed are those of the authors of each contribution and do not necessarily represent the consensus of SIMA. Comments on this document are most welcome and should be sent to the editors or to the SIMA coordinator:

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1. INTRODUCTION

SIMA Summary

Goal

To reduce malaria resulting in improved health and well-being, increased agricultural productivity and poverty alleviation.

Project Purpose

To develop and promote methods and tools for malaria control through improved agricultural practices and proper management and utilization of natural resources. These will be based on scientifically documented interactions between agricultural production systems and malaria, and will complement existing antimalarial approaches.

SIMA Outputs

Output 1 - Identify, validate and demonstrate "integrated anti-malaria intervention portfolios" that will reduce the disease in specific agro-ecosystem settings. Research will concentrate on a number of *SIMA Benchmark Sites* where agriculture intersects with malarial problems. These studies will identify and test combinations of antimalarial interventions in real-life situations. Based on these findings, a series of "integrated antimalarial portfolios" will be developed that have proven effective to reduce malaria in specific conditions. An example of an integrated intervention would be a combination of land-preparation practices, the choice of crops and cropping patterns, appropriate small-scale irrigation approaches, education on the use of bed nets, and the use of medicinal and mosquito-repellant plants. The socio-ecological (including gender) and local health-support systems currently in operation in malaria-affected areas will be reviewed and characterized. The SIMA research teams will validate malaria-control tools and practices (current and new approaches and traditional practices).

Output 2 - Build capacity and encourage the exchange of experience. The core of SIMA's work centers on some 30-50 collaborative research projects over 5 years. These projects will create links between new colleagues in the agriculture, malaria/health and development communities. A longer-term impact of SIMA will be the creation of lasting ties between these three sectors to support the creation of integrated antimalarial policies at the national level. Gender balance will be an important aspect of national-level capacity building. Specific capacity-building components of SIMA include the following:

- A Ph.D. program.
- A postdoctoral scientist program.
- Creating and delivering teaching and training materials for university courses and supporting the work of agricultural-extension and implementing NGOs.

Output 3 - Create a knowledge base of practical information on agricultural solutions to malaria reduction. Create a body of new research knowledge on interactions between malaria and agriculture. Compile an inventory and scientific validation of existing research on malaria and make it available to all interested users. Publish and deliver practical information to the development and agricultural-extension communities and to agricultural and health-sector policy makers and implementers.

Output 4 - Increase awareness of the potential of environmental interventions to reduce malaria in the development, agricultural and health communities. Implement an information and advocacy campaign to encourage the incorporation of malaria-reducing farming practices in development projects, agricultural/water interventions and health policies. SIMA researchers provide input to key malaria-strategy and -policy conferences on the yearly agriculture/health/development calendar, by presenting papers and by representing SIMA on the relevant committees.

Output 5 - Build an International Network on Malaria and Agriculture. One of the important results of SIMA will be the creation of an active network of specialist organizations that will bring new skills and expertise to current antimalarial efforts. New malaria-reduction approaches brought by SIMA will be transferred to the malaria and health fields; agricultural research and extension; implementation and rural development; and educational groups and community-based organizations. The purpose of the network is to serve as a change catalyst in malaria-stricken countries, to help them create the agricultural policies and strategies that will reduce malaria in relevant areas.

Impacts

Reduce malaria. Reduction of malaria in high-risk areas and improved livelihoods for millions of poor people.

Encourage antimalarial practices. Introducing and promoting changes in farming and social practices that significantly prevent or reduce malaria.

Stimulate new policy thinking. Joint development and institutionalization of agro-ecosystem management strategies for malaria reduction among communities and national-agricultural and health-research programs in malaria-endemic countries.

Build health/agriculture partnerships. Partnerships between the agriculture and health sectors created on agro-ecosystem management for human health.

Embed research findings. Embedding of research findings into national, development and public-health programs, the work and thinking of NGOs, community-based organizations (CBOs) and, through them, the practices of local communities.

These Proceedings

The Special SIMA Seminar on Malaria in Irrigated Agriculture at the 18th ICID International Congress on Irrigation and Drainage was one of the activities aimed at increasing awareness in the agricultural community on the potential of environmental interventions to reduce malaria under Output 4 of SIMA. This document contains papers and abstracts submitted for this seminar in Montreal, Canada. The authors themselves are responsible for their contributions and it is hoped that the publication of these proceedings will stimulate discussions among participants of the seminar as well as in the wider SIMA Network.

This seminar is organized by SIMA, the CGIAR Systemwide Initiative on Malaria and Agriculture, in collaboration with the International Water Management Institute (IWMI). This and subsequent scientific seminars will gather experts on malaria and agriculture to contribute to the development of a comprehensive knowledge base on malaria and agriculture. The SIMA conferences will provide opportunities for scientists to present research outputs and recommendations to the actual implementers and policy makers on how various agro-ecosystem approaches can reduce malaria. A second seminar this year is planned at the 3rd MIM (Multilateral Initiative on Malaria) Pan-African Conference on Malaria, November 2002 in Arusha, Tanzania.

The International Commission on Irrigation and Drainage (ICID) hosts a large international congress every third year in a different country. SIMA is grateful to the organizers of the 18th Congress in Montreal for facilitating a special seminar on Malaria in Irrigated Agriculture.

2. ENGINEERING AND MALARIA CONTROL: LEARNING FROM THE PAST 100 YEARS

Flemming Konradsen,[1,2] Wim van der Hoek,[1] Felix P. Amerasinghe,[1] Clifford Mutero[1,3] and Eline Boelee[1]

Historically, engineering and environment-based interventions have played an important role in the prevention of malaria in Asia. However, with the introduction of DDT and other potent insecticides, chemical control became the dominating strategy. The renewed interest in environmental-management-based approaches for the control of malaria vectors follows the rapid development of resistance by mosquitoes to the widely used insecticides, the increasing cost of developing new chemicals, logistical constraints involved in the implementation of residual-spraying programs and the environmental concerns linked with the use of persistent organic pollutants. To guide future research and operational agendas focusing on environmental-control interventions, it is necessary to learn from the experiences before the introduction of insecticides. The objective of this paper is to describe a few cases highlighting early experiences using agricultural engineering and land and water management to control malaria vectors in Asia focusing on the period 1900 to 1950. The selected cases will be discussed in the wider context of environment-based approaches for the control of malaria vectors including current relevance. The paper is based on an extensive literature review to identify original articles, research letters, reviews and government-commissioned technical reports.

Background

As early as the sixth century BC the Greeks and the Romans were aware of the association between fevers and stagnant waters and swamps. This awareness led to drainage interventions aimed at improving the health of the nearby population and increasing agricultural production (Gilles and Warrell 1993). Later, deliberate drainage activities focusing on improvements in public health were taken up by other communities throughout much of Europe. However, not until many centuries later, with the discovery of the role of mosquitoes as the vector of malaria in India in 1897, were engineers provided with a much-improved basis for designing specific interventions to control malaria. Some of the high-profile cases where engineers played a key role in reducing the disease through

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environmental-management interventions come from the construction of the Panama Canal and the drying of the Pontine marshes in Italy where land filling and drainage played an important role. Also, the water-management activities of the Tennessee Valley Authority in the USA are prime examples of the systematic application of environmental-management measures for the prevention and control of malaria (Rafatjah 1988; Hinman 1941). Many less-well-known examples exist where engineering and environment-based interventions have played an important role in the prevention of malaria, and these examples need to be revisited and lessons drawn to better design measures relevant for today. Most of these examples come from the first half of the twentieth century, before DDT and other potent insecticides became available and chemical-based vector control became the dominating strategy, and engineering-based interventions lost their importance. The renewed interest in environmental-management approaches for the control of malaria follows the rapid development of resistance to the insecticides by mosquitoes, the increasing cost of developing new chemicals and the logistical constraints involved in the operation of chemical vector-control programs. Similarly, environmental concerns raised over the use of persistent organic pollutants have made national governments and international organizations more interested in looking for alternative measures to control malaria vectors. In recent strategies, the World Health Organization (WHO) has advocated the use of a multitude of interventions in the control of malaria. As such, engineering and environmental-control measures may again become an important part of vector-control initiatives.

The objective of this paper is to describe a few cases highlighting early experiences using agricultural engineering and land and water management to control malaria vectors in Asia. These examples will be used as the starting point for a wider discussion presenting preliminary findings from an ongoing effort to review literature covering the 1900–1950 period with a specific focus on environmental management for malaria-vector control in Asia. The paper attempts to discuss past experiences that are of current relevance.

Methodology

This paper is based on the identification of research reports published primarily in the period 1900–1950 in the form of original articles, research letters, reviews or government-commissioned technical reports. The publications have been identified through a manual search of all publications listed in annual reference books of Index Medicus, the index catalogues of the Library of the Surgeon General's Office of the US Army and catalogues of the National Library of Medicine in the USA. An electronic search was also performed on the Medline database to identify review papers of relevance for the 1900 to 1950 period. Textbooks on malaria control and WHO publications were reviewed to identify additional relevant publications that may not have been included in the main reference systems used for the review. The search was guided by the use of selected key words including *Anopheles*, mosquitoes, vector control, malaria, malaria eradication, fever, black water fever, tropical disease control and sanitary engineering. Relevant publications in English, German, Dutch, Danish and Swedish were requested from central libraries located primarily in the UK, Denmark, US and India. More than 60 original published papers were identified. Only limited emphasis was given to publications from the Dutch East Indies (Indonesia), since these have been covered by Takken et al. (1990).

Malaria-Vector-Control Interventions

The experiences from Mian Mir: Vector control in an arid area with large-scale irrigation

When reviewing the early documentation on environmental management for malaria control in Asia for the twentieth century the antimalarial operations at Mian Mir in Punjab and interventions at Klang Town and Port Swettenham of Malaysia stand out. The two cases were reported on and discussed intensively among the malaria-research community in the early part of the twentieth century and more than 20 research and technical references have been identified from this period. Mian Mir, today a suburb of Lahore, was selected as an experimental site for anti-larval operations in 1901 (Christophers 1904). The interventions to be tested at Mian Mir were partly based on observations and preliminary anti-mosquito efforts undertaken at Freetown, Accra and Lagos in West Africa around the turn of the century (Stephens 1904). The interventions were also inspired by the initial vector-control activities initiated in Ismailia, Egypt, by the Suez Canal Company under the guidance of Ross (Boyce 1904).

The settlement at Mian Mir included an army garrison and scattered traditional, residential and farming areas. The area was characterized by very flat terrain resulting in very limited natural drainage. Also, the soil was, for the most part, impervious to water after one or two hours of rain. The storm-water drains that were in place in the area were without sufficient fall and seemed to do more harm than good. Although the area was arid, even the slightest shower of rain would result in surface puddles until dried up by the sun. Another characteristic feature of the area was the irrigation network of shallow channels from which farmers drew water by means of Persian wheels to irrigate field crops and home gardens. Extensive baseline investigations were carried out to assess the level of malaria in the area, describe seasonal differences in transmission and to identify important breeding sites for the mosquito vector (Christophers 1904). A special focus of the investigation was the burden of malaria among the army personnel and the breeding within the vicinity of army barracks. The entomological investigations, including dissections, led to the conclusion that *Anopheles culicifacies* was the only vector of importance for malaria transmission in Mian Mir and this had a great influence on the design of specific interventions (James 1903a). *An. culicifacies* was found to breed extensively in the smaller irrigation channels (watercourses), especially where vegetation along the edges reduced water velocity or during periods of canal closure when pools were formed in the channels. During specific periods the watercourses would overflow creating breeding opportunities along the channels. The poorly designed and maintained small earthen drainage canals were other important breeding sites. The practice of providing excess irrigation water to small gardens immediately surrounding homesteads created breeding opportunities too. The baseline investigations indicated that the seasonal pattern of malaria was related to rainfall, temperature and irrigation water releases. Also, it was found that the army quarters closest to the irrigation canals had the highest risk of malaria (James 1903a, 1903b).

Measures implemented to reduce vector breeding at Mian Mir included repairing the banks of irrigation channels and clearing these of silt and vegetation to reduce overflow. Additionally, depressions next to channels were reduced by leveling. The ten watercourses closest to the army barracks were inspected daily during the active breeding season and debris were removed and attempts made to reduce pooling. If the weekly inspection of garden sections of the army compound found suspected anopheline breeding pools these were emptied and filled with earth, as much as possible. During the rainy period, June and July, great efforts were made to reduce the breeding potential of the often quite large pools formed in drainage canals either by using buckets to empty the pools or by applying kerosene oil. Continuous inspection of housing areas resulted in the identification of potential breeding sites, e.g., domestic water containers, and these were dealt with. Superficial small drainage lines were also created to remove water from larger open areas and more than 250 larger soil depressions were permanently filled. In addition to the environmental modifications and manipulations undertaken in the area, mass distribution of quinine was practiced (Christophers 1903; James 1903b).

The anti-larval measures implemented at Mian Mir had an effect on larval breeding for the specific habitats covered but the effect on adult mosquito abundance within the settlements was limited. However, for the early phase of the control efforts no clear conclusion could be reached as to what effect the interventions actually had on malaria (James 1903b). In 1909, the Government of India appointed a committee to investigate the experiences at Mian Mir and came out with a general negative finding as to its effectiveness on reducing malaria. Ross (1910) made several contributions to the discussions on Mian Mir and he claimed that the work of the committee did not have sufficient basis for their conclusions and felt strongly that the experiences of Mian Mir should not determine the future of vector control for all of India. Earlier, Ross and others had been very critical of the design followed at Mian Mir and claimed that not enough had been done to prevent vector breeding over a sufficiently large area to actually measure a reduction in vectors within human habitations (Ross 1904a, 1904b). Also, Ross found the investments in anti-larval control too limited and completely out of proportion with the cost of malaria to the government. When considering the cost to the government from the sick soldiers at Mian Mir alone the expenditure for malaria prevention only made up a 1/400th proportion of this cost (Ross 1910). In 1924, following a visit to Mian Mir, Watson (1924) concluded that the area was never sufficiently drained and proper outlets should have been constructed from the drainage canals, possibly with pumping devices, to assist the drying of canals. The Mian Mir case was also one of the first documented cases resulting in a heated debate over the role of irrigation in the spread of malaria and how to combine the necessity of food production and livelihoods with public health (Giles 1904; Anonymous 1910). It also gave rise to some of the fundamental questions for effective malaria-vector control, i.e., how large an area should be covered to have an effect on the protection of human settlements? and how much reduction in adult vector population will have to be achieved to measure an impact of malaria on human beings. The discussion of cost-effectiveness of proposed interventions was central in the discussions of the Mian Mir experiences.

The effect of drainage and landscaping in malaria control at Klang and Port Swettenham

Around the same time that the Mian Mir project was being planned, malaria-control activities were initiated in Malaysia. The cases from Malaysia are examples of government-department staff reacting rapidly to the new avenues for control, made possible thanks to the discovery of the role of mosquitoes in the transmission of malaria.

In 1901, the town of Klang, with around 3,500 people, was located in hilly terrain on the Klang river in one of the most important districts of rubber and coffee cultivation. The town experienced severe problems with malaria, resulting in government officials being continuously ill and laborers being unable to work (Watson 1905). Entomological surveys in the town of Klang found that the permanent swamps in and around the town and the large number of open wells and pools along the road provided breeding opportunities for anopheline mosquitoes. Groundwater was very high at the foot of the small hills surrounding the town and this created flooded conditions following rains (Watson 1903, 1924). The first activities undertaken with the assistance of government departments and private landowners were to remove dense jungle vegetation and undergrowth from within and immediately around the town. Most of the swamps within the town were also filled or drained. Large-scale drainage systems were put into operation, based on the construction of concrete turf-lined inverts. This kind of drain was found to be relatively inexpensive and the turf sides facilitated water inflow from the subsoil. Special constructions were designed to prevent tidal water from entering the drains. Open drains that followed the contour of the hill at its lowest point were constructed along the foothills (Watson 1903, 1924). The idea behind this was to capture the water from the springs and surface runoff before it could accumulate on the plains outside the town. Within a few years, the entire town perimeter was drained, with the cost primarily covered by the state and, to a lesser extent, by private landowners and private enterprises. A few years later, experiments with subsoil drainage systems were introduced with a good result in terms of improved drainage and reduced mosquito populations (Watson 1929).

Further down the Klang river was Port Swettenham surrounded by mangrove swamps. The harbor at Port Swettenham was constructed during the late 1890s and, soon after the construction, an alarming number of malaria cases were registered. Almost the entire labor force was affected and government officials had to be hospitalized in great numbers. Also, the ship crews were severely attacked when the harbor became operational.

As a means of vector control, earthen bunds were established between the sea and the residential areas to prevent the inflow of tidal water, and behind the bunds a network of surface drains was constructed. Each drainage outlet was fitted with an iron pipe with a construction allowing for water to be released during low tide and closed during high tide (Travers 1903, 1904). One problem experienced along the stretch from Klang Town to Port Swettenham was the effect of the railway line since this obstructed the natural drainage flow. The railway was constructed on a bund. Breeding opportunities for the vector of malaria were created behind the bund, and culverts had to be constructed at regular intervals along the railway bund to reduce pooling (Watson 1905). Vegetation clearance, small-scale landscaping and the application of crude kerosene oil to suspected breeding sites were also carried out along with the major drainage activities. Similarly, in both Klang and Port Swettenham the environmental interventions were supported by the treatment of cases with quinine. The interventions were the result of detailed planning and cost estimates, and included contributions from a diverse set of actors including the Government Railway Engineers, Harbor Master, District Officer and District Surgeon. The results of the interventions in both Klang Town and Port Swettenham were very impressive and well documented with dramatic reductions in the number of malaria cases (Travers 1903, 1906). One of the conclusions reached by Watson was that the subsoil or surface drainage would be much preferable when compared with control activities depending on the continuously monitoring of small surface-water collections. Also, the permanent types of drainage allowed for the establishment of human settlements in the reclaimed area. The experience with subsoil drainage for vector control at Klang was later introduced and further advanced in many parts of Malaysia, Singapore and elsewhere in Asia (Watson and Hunter 1921; Scharff 1935; Tweedie 1940). The experiences from Malaysia provided important inputs into the design of malaria-vector-control activities in rural USA, and the exchange of experiences between the research station at Klang and the Rockefeller Foundation facilitated this transfer of knowledge from Malaysia to the USA (Watson 1929).

Managing streamwater flows for the prevention of malaria: Vector breeding in Sri Lanka

In Sri Lanka (Ceylon, from the beginning of the British period until 1972), the importance of rivers and streams in generating large numbers of the most important vector of malaria has been well documented and the relation between river water flow and mosquito breeding was known early in the twentieth century (Carter and Jacocks 1929; Chellappah 1939).

In 1938, a range of experiments was initiated to reduce the breeding of vectors that occurred, especially outside the rainy season or during periods of drought when pools would form in large numbers in the stream and river beds. A number of engineers from the medical and sanitary services designed a range of different types of siphons and small dams in an attempt to flush a stretch of river to eliminate the breeding of mosquito larvae (Worth and Subrahmanyam 1940). The rationale behind the control intervention was the removal of mosquito larvae from their natural breeding sites by the creation of strong currents and the final stranding of the larvae when the water level falls. More than 30 installations were placed to regulate flows in five different river systems. The dams constructed across the rivers were 6 to 21 m wide, making volumes between 500 and 2,500 m^3 available for flushing. The peak discharges during a "flush" from the siphons ranged from 0.3 to 0.6 m^3/s (10 to 23 cusecs), generating a water-flow velocity of 0.2 to 0.5 m/s. The engineers working in Sri Lanka were inspired by the positive results from Malaysia with the anti-larval flushing of waterways and adopted a modified version of the automatic siphons used in Malaysia (Nicholas 1939). Most of the experiments related to the technical and operational feasibility of installing siphons in Sri Lanka but aspects of cost were also discussed for the various types of dams and siphons tested. Less emphasis was placed on the assessment of the effectiveness of the interventions on the actual breeding of mosquitoes and possible implications for the transmission of malaria. The main findings from the 2 years of experimentation with the operating siphons were that their effectiveness depended very much on the local stream conditions and the conditions of the banks. The amount of silt and floating vegetation carried by the river also determined the efforts required for maintenance of the structures, and the effectiveness of flushing devices was reduced substantially during periods of very low river flow. However, the early experiments with siphons in Sri Lanka identified avenues for further testing, and hand-operated siphons were seen as more promising than the fully automatic designs despite the higher manpower investment in operations. Following the work in Sri Lanka, experiments were continued in India and elsewhere in Asia. Recently, different options for the management of water levels in streams in Sri Lanka have been discussed and the linkages in stream water flows, breeding and malaria transmission documented (Konradsen et al. 1998; Amerasinghe et al. 1999). Experiments are currently under way to further assess the possibilities of regulating water flows as a means of controlling the breeding of malaria vectors.

Discussion

The review of literature from the first half of the twentieth century shows an impressive ingenuity in experimenting with malaria-vector control. These activities were a concerted effort by medically qualified staff, entomologists, engineers and public administrators across many different departments, such as agriculture, health, transport, urban planning and the army. This interdepartmental and interdisciplinary collaboration is crucial for the success of environmentally based malaria-control interventions and a feature too often lacking in the activities implemented today. However, the involvement of the local communities in malaria control during the early twentieth century was quite different from the approaches followed by many of the government agencies and NGOs of today. The approaches followed earlier were clearly top-down and were based on strict incentive and disincentive systems with heavy structures to support enforcement.

In 1979, the WHO Expert Committee on Vector Biology and Control classified environmental management for vector control as environmental modifications, environmental manipulations, and modification or manipulation of human habitation or behavior (WHO 1980). The classification covers the land- and water-management activities or general-engineering-based interventions tested early in the twentieth century. However, one of the definitions that WHO provided in 1979 makes it clear that the modifications made to control the disease vectors must not have "adverse effects on the quality of human environment." This may rule out quite a few of the interventions practiced earlier depending upon the interpretation of the definition. Many of the permanent modifications of the environment resulted in massive destruction of what today would be categorized as valuable ecosystems, such as wetlands, freshwater streams or mangrove swamps. Similarly, some of the implemented interventions resulted in forced relocation of population groups and may not apply to the ideal social standards of today. However, as with most of the development activities during the greater part of the twentieth century, the implications for the natural environment were never given much attention.

What is very striking in the literature from the early twentieth century is the emphasis on the costing of interventions and, to some extent, also on the comparison of interventions based on simple cost-effectiveness measures. Similarly, the direct cost of malaria to government departments or the wider economic cost of the malaria burden to production systems or society features prominently in the literature. The need for better estimates of the economic cost of disease to communities and governments has also received increasing attention over the past years. Clearly, the priorities during the early twentieth century and the selection of indicators of economic cost of disease were a reflection of the political systems in place and not necessarily the priorities of the local communities. However, the very detailed estimations of cost for the different engineering and environment-based vector-control programs provide a valuable input even today for the identification of various cost components, and the resources needed for implementation, and make it possible to discuss the likelihood of financial viability. For example, it is likely that the significant labor inputs required by many of the interventions pursued during the early and mid-twentieth century would have to be replaced by increased mechanization to be cost-effective today. Many of the environmental interventions could be designed to have additional economic benefits over and above disease reduction as the experimentation with alternate wet and dry irrigation in rice cultivation (van der Hoek et al. 2001) and the secondary benefits of drainage activities resulting from land reclamation or increased agricultural productivity (Harmancioglu et al. 2001) have shown.

Most of the successful control programs implemented during the peak of the environmental management for the vector-control era were undertaken along with large-scale use of chemotherapy or oil-based anti-larval products. This makes it difficult to isolate the contribution made by engineering-type interventions to overall disease control, while the effect on vector abundance was easier to quantify. Even today, environmental vector-control options would always be combined with a strategy for the early detection and treatment of malaria cases.

Of the many different interventions discussed, drainage is clearly one of the oldest and best-documented methods of environmental vector control and has been implemented as surface, subsurface or vertical drainage systems. Nichols (1907) published a detailed account of the early malaria-control activities undertaken in the West Indies, emphasizing the drainage interventions supervised by army engineers. Scharff (1935) and Craig (1937) published detailed technical accounts of the different options for vector control through drainage, drawing heavily on the experiences from Malaysia and Singapore. The various options were described in the context of different vector habitats. LePrince (1920) argued strongly for the use of permanent drainage and the involvement of health officials when planning the development of townships in the USA.

Different stream- and river-water-management interventions and strategies have been tried out to reduce vector breeding. In the 1930s, in the Philippines, Russell tested the use of sluice gates to regulate water levels, where he combined the emptying of an upper section of a stream with the flushing of the section below and found very positive results on the control of the local vector. These and other experiments were discussed in a key publication by Williamson and Scharff (1935) where the different approaches relating to "sluicing" and "flushing" of streams were reviewed. The recent experiences from Sri Lanka not only included options related to flushing but also a more general discussion of how to create a water level, above pooling level, using existing irrigation-related infrastructure (Konradsen et al. 1998; Matsuno et al.1999).

Clearly, a wealth of knowledge and innovations can be drawn from the experiences generated during the early twentieth century. To make the best use of the experiences a renewed interest is needed in engineering methods for vector control. The site-specific nature of the types of interventions discussed will require a strong local research capacity to support field-testing. One step in this process of revitalizing the research efforts has been the identification of documents in the process of establishing the research agenda for the Systemwide Initiative on Malaria and Agriculture (SIMA). These documents, along with the reviews published in the past (Takken et al. 1990; Rafatjah 1988; Onori et al. 1993; IRRI 1988), will be an important starting point for future experiments. Efforts to reduce the global burden of malaria need the input from professionals in the area of land and water management.

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Literature Cited

Amerasinghe, P.H.; F. P. Amerasinghe; F. Konradsen; K. T. Fonseka; and R. A. Wirtz. 1999. Malaria vectors in a traditional dry zone village in Sri Lanka. *American Journal of Tropical Medicine and Hygiene* 60: 421-429.

Boyce, F.R.S. 1904. The effects of the anti-malarial campaign at Ismailia. *Journal of Tropical Medicine*, vii: 75.

Carter, H.F.; and W. P. Jacocks. 1929. Observations on the transmission of malaria by anopheline mosquitoes in Ceylon. *Ceylon Journal of Sciences* (D) 2: 67-86.

Chellappah. 1939. Malaria control in Ceylon. *The Journal of the Ceylon Branch of the British Medical Association*, xxxvi, 293-311

Christophers, S.R. 1904. Second report of the anti malarial operations at Mian Mir, 1901-1903. *Scientific Memoirs by the Office of the Medical and Sanitary Departments of the Government of India.*1-37. Calcutta.

Craig, W.J.F. 1937. Drainage work in New Changi Cantonment, *J. Roy. Army M. Corps* 68 (15): 73.

Giles, G.M. 1904. The anti-malarial operations in Mian Mir. *Journal of the Royal Army Medical Corps*, iii: 131-133.

Gilles, H.M.; and D. A. Warrell. 1993. *Bruce-Chwatt's Essential Malariology.* 3th edition. London: Arnold.

Harmancioglu, N.; N. Alpaslan; E. Boelee. 2001. *Irrigation, health and the environment: A review of literature from Turkey.* IWMI Working Paper 6. Colombo, Sri Lanka: International Water Management Institute.

Hinman, E.H. 1941. The management of water for malaria control. Symposium on Human Malaria, Philadelphia, USA, December 1941: 324-32. Philadelphia, Pasadena, USA.

Anonymous. 1910. The lesson of Mian Mir. *Journal of Tropical Medicine*, xiii: 146-151.

IRRI (International Rice Research Institute). 1988. Vector-borne disease control in humans through rice agroecosystem management. *Proceeding of the workshop on research and training needs in the field of integrated vector-borne disease control in the riceland agroecosystems of developing countries*, 9-14 March, Los Banos, Philippines.

James, S.P. 1903a. A report of the anti malarial operations at Mian Mir (1901-1902). *Reports to the Malaria Committee of the Royal Society.* 27-77. London.

James, S.P. 1903b. First report of the anti malarial operations at Mian Mir, 1901-1903. *Scientific Memoirs by the Office of the Medical and Sanitary Departments of the Government of India.* 1-53. Calcutta.

Konradsen, F.; Y. Matsuno; F. P. Amerasinghe; P. H. Amerasinghe; and W. van der Hoek. 1998. *Anopheles culicifacies* breeding in Sri Lanka and options for control through water management. *Acta Tropica* 71: 131-138.

LePrince, J.A. 1920. Drainage as an antimalarial measure. *American Journal of Public Health* x: 120-123.

Matsuno, Y.; F. Konradsen; W. van der Hoek; P. H. Amerasinghe; and F. P. Amerasinghe. 1999. Control of malaria mosquito breeding through irrigation water management. *International Journal of Water Resources Development* 15: 93-105.

Nichols, F.P. 1907. The effects of large drainage works on the prevalence of malaria. *Journal of the Royal Army Medical Corps* viii: 343-360.

Nicholas, W.A. 1939. Four-day automatic sluice. *Journal of the Malaya Branch, British Medical Association* 3: 44-46.

Onori, E.; P. F. Beales; and H. M. Gilles. 1993. Rationale and technique of malaria control. In *Bruce-Chwatt's Essential Malariology,* ed. H. M. Gilles and D. A. Warrell. 3th edition. London: Arnold. pp. 196-265.

Rafatjah, H.A. 1988. Malaria vector control: Environmental management. In *Malaria – Principles and Practice of Malariology*, ed. W. H. Wernsdorfer and I. McGregor. 1: pp. 1135 – 1173.

Ross, R. 1904a. The anti-malarial experiment at Mian Mir, Punjab, India. *Journal of Tropical Medicine* vii: 255.

Ross, R. 1904b. The anti-malaria experiment at Mian Mir. *British Medical Journal* ii, 632-635.

Ross, R. 1910. Report on the measures taken against malaria in the Lahore (Mian Mir) Cantonment. *Lancet* ii: 1371.

Scharff, J.W. 1935. An essay on anti-malarial drainage for engineers and doctors. *Journal of the Malaya Branch, British Medical Association* 8:165-169.

Stephens, J.W.W. 1904. The anti-malarial operations at Mian Mir (Punjab). *Lancet*, i: 637.

Takken, W.; W. B. Snellen; and J. P. Verhave. 1990. *Environmental measures for malaria control in Indonesia: An historical review on species sanitation.* Wageningen Agricultural University Papers 90-7. Wageningen, Netherlands: Wageningen Agricultural University.

Travers, E.A.O. 1903. An account of anti-malarial work carried out with success in Selangor, one of the Federated States of the Malay Peninsula. *Journal of Tropical Medicine* vi: 283-291.

Travers, E.A.O. 1904. An account of anti-malarial work carried out with success in Selangor, one of the Federal States of the Malay Peninsula. *Indian Medical Gazette*. xxxix: 28-30. Calcutta.

Travers, E.A.O. 1906. A further report on measures taken in 1901 to abolish malaria from Klang and Port Swettenham in Selangor, Federated Malay States. *Journal of Tropical Medicine* lx: 197.

Tweedie, D.R. 1940. Fascine drainage as antimalaria measure. *Journal of the Malaya Branch, British Medical Association* 4: 167-171.

Van der Hoek, W.; R. Sakthivadivel; M. Renshaw; J. B. Silver; M. H. Birley; and F. Konradsen. 2001. *Alternate wet/dry irrigation in rice cultivation: A practical way to save water and control malaria and Japanese encephalitis?* IWMI Research Report No. 47. Colombo, Sri Lanka: International Water Management Institute.Watson, M. 1903. The effect of drainage and other measures on the malaria of Klang, Federal Malay States. *Journal of Tropical Medicine* 349: 368.

Watson M. 1903. The effect of drainage and other measures on the malaria of Klang, Federal Malay States. *Journal of Tropical Medicine* 349: 36.

Watson, M. 1905. The effect of drainage & other measures on the malaria of Klang, Federated Malay States. *Journal of Tropical Medicine* viii: 100-104.

Watson, M.; and P. S. Hunter. 1921. *The prevention of malaria in the Federated States: A record of 20 years' progress*. 2nd. ed. London: John Murray. 408.

Watson, M. 1924. Observations on malaria control, with special reference to the Assam Tea Garden, and some remarks on Mian Mir, Lahore Cantonment. *Transactions of the Royal Society of Tropical Medicine and Hygiene* xviii, 147-161.

Watson, M. 1929. Twenty-five years of malaria control in Malay peninsula, 1901-1926, *Journal of Tropical Medicine* 32: 337-340.

WHO (World Health Organization). 1980. *Environmental management for vector control.* Fourth report of the WHO Expert Committee on Vector Biology and Control, Technical Report Series No. 649. Geneva.

Williamson, K.B.; and J. W. Scharff. 1936. Anti-larval sluicing, *Malayan Medical Journal* 11:123-150.

Worth, H. N.; and K. Subrahmanyam. 1940. Anti-larval flushing of rivers and streams in Ceylon. *Journal of the Malaria Institute of India* 3: 81-92.

3. MALARIA AND IRRIGATED AGRICULTURE IN ZIMBABWE: IMPACT ASSESSMENT, COSTING AND QUANTIFICATION UNDER FIELD CONDITIONS

A. Senzanje,[1] E. Hackenitz[2] and M. Chitima[3]

It is generally assumed that irrigation schemes create conditions that enhance mosquito breeding and hence contribute to the transmission of malaria. Malaria is among the five major causes of death in Zimbabwe. This paper presents the means and findings of an assessment of the impact of irrigation schemes on malaria in Zimbabwe. Data from large-scale irrigation schemes show that 11 to 49 percent of the estate employees suffer from malaria, depending on control measures in place. Malaria contributes up to 38 percent of the total labor days lost to production per annum. Mosquito-control costs, through insecticide and larvicide sprays, range from Z$14/irrigated ha/year to Z$32/irrigated ha/year. Disease control through prophylaxis costs about Z$4.50/person/year in 1997. These costs are rising to unsustainable levels and income through irrigation cannot keep up with the steady rise in costs of chemicals and medicines.

The assessment of impacts of small-scale irrigation on malaria prevalence under field conditions is complicated due to scarce data and various confounding factors. These include record-keeping practices at health facilities, misdiagnosis, movement of people to and from irrigation schemes, an impact from natural features and irrigation water management. A methodology is proposed to assess the impact on malaria from the complex of irrigation, health measures, local natural features, events, customs and habits. The use of nonspecific data in combination with a multispectral approach is elaborated.

Introduction

The irrigated area in Zimbabwe is over 150,000 hectares. Irrigated agriculture in both large-scale and small-scale schemes contributes significantly to agricultural production in the country. Apart from being essential for national food security, agriculture is the second largest earner of foreign currency. It accounts for 40 percent of merchandise exports, and provides 70 percent of the total formal and informal export employment (IFAD 1998).

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Irrigation is known for a negative impact on the environment, as a result of the environmental modification that occurs with irrigation development. Irrigation systems have been associated with an increase in, and the spread of, water-related diseases, such as malaria. The infrastructure in irrigation schemes has been found to create or enhance ecological environments that are favorable for the transmission of malaria and other vector-borne diseases (Hunter et al. 1982; Chimbari et al. 1993; Oomen et al. 1994; Bolton 1994).

Annually, Zimbabwe has about 139 clinical malaria cases[1] per 1,000 persons and a hospitalization rate of 28.6 patients per 1,000 persons. Malaria contributes about 11 percent to all recorded deaths, being one of the five major causes of death (National Health Profile 1998). High numbers of malaria cases are often associated with irrigated agricultural activities. The impact of malaria includes loss of life, loss of productive time, burdening of health services, increased costs of disease control and a decrease in the welfare of affected individuals and communities. Given the above scenario, several questions arise. How much does irrigated agriculture contribute to the national malaria problem? What are the direct and indirect impacts of malaria on agricultural-production enterprises and what are the costs of disease prevention? How can an impact from small-scale irrigation schemes be estimated?

This paper presents findings of an assessment of malaria problems in irrigation schemes in Zimbabwe undertaken for the Ministry of Agriculture in 1997 (Hackenitz and Senzanje 1997). The aim of the assessment was to identify associations between irrigated agriculture and diseases and quantify these. Disease prevalence, relative impact on agricultural productivity in economic terms and the cost of various malaria-control interventions in practice are discussed. Special attention is paid to assessing an impact from small-scale irrigation under field conditions. A methodology is proposed that uses inadequate health data in combination with a multispectral approach.

Malaria in Large Irrigation Estates

The results herein are from two large irrigation estates: Hippo Valley Estates (HVE)[2] and ARDA, Chisumbanje,[3] and from a range of smallholder schemes. The choice of the small-scale sites intends to bring out the diversity and disparity in the irrigation schemes in different ecological regions.

A commonly used classification of natural regions in Zimbabwe distinguishes agro-ecological regions based on rainfall, altitude and temperature to determine the farming systems appropriate for such areas. Generally, Region V has low altitude (around 350 m), low rainfall (<450 mm) and temperatures of around 25 ºC, making it most suitable for extensive farming practices. Malaria is endemic in this agro-ecological region. Region IV has precipitation ranging from 450 to 650 mm, is appropriate for semi-extensive farming and is generally a malaria-endemic area. Region III has higher rainfall (650-800 mm) and slightly higher altitude than region IV and can be used for semi-intensive farming. With lower temperatures, Regions III, II and I, hardly have malaria.

[1]People diagnozed with malaria, based on symptoms and physical examination.

[2]Health data from Hippo Valley Estates are released courtesy of Dr. Davey of Hippo Valley Estates.

[3]Health data from ARDA Chisumbanje are released courtesy of Mr. Noko, Estate Manager of ARDA Chisumbanje.

In addition to ecological regions, the selected estates and schemes differ in size, mode of operation, management and resources endowment. These aspects all impact on malaria prevalence, control measures and costs. As control programs in small-scale schemes lack quantified site-specific documentation, data from large-scale irrigation estates were obtained to estimate the economic aspects of malaria control in irrigation. Details of the two large irrigation estates are given in table 1.

Table 1. Characteristics of the two large estates.

Aspect	Hippo Valley Estates	ARDA Chisumbanje
Altitude (m)	300	410
Ecological region	V	V
Mean annual rainfall (mm)	500	450
Mean temperature (^{0}C)	25	24
Size (ha)	10,000	2,500
Population (number)	30,000	4,600
Water source	Dams	River
Water conveyance	Canals	Pipe/Canal
Irrigation method	Surface	Surface
Malaria endemicity	Yes	Yes

Hippo Valley Estates (HVE)

These are privately owned sugarcane estates with about 10,000 hectares under irrigation with slightly over 30,000 people who reside in the area. Field-water application is mainly by furrow irrigation. Irrigation water is obtained from various dams off the scheme, and then conveyed to the estates by a network of canals. There are over 200 night storage dams and more than 60 kilometers of major canals on the estates. Excess and runoff water is collected by a series of subsurface and surface ditch drains. In terms of this assessment, only two sections (section 17 and 4) were studied. Hippo Valley Estates are served by a well-endowed hospital with a full complement of services.

ARDA Chisumbanje Estates

These are estates under parastatal management (sub-vented company) with about 2,500 hectares under irrigation. Cotton, wheat and sugarcane are the main crops. The estates have, on average, about 4,600 employees, living in the area. Irrigation water comes from the Save river and is pumped directly to the estates' three night-storage dams through an underground pipeline and a 12-km line canal. Water application to the fields is by furrow irrigation. Excess and runoff water is collected by tail-end drains. The estates have a health clinic with basic amenities and services.

Data Collection

Detailed data collection on the studied schemes involved on-site assessment of scheme design, construction and environmental risk factors. Health data were collected from the clinic or hospital servicing the workers on the irrigation estates. Calculations of annual cost of control programs are based per person, per irrigated hectare or per unit of irrigation water. Other data, such as labor days lost to illness, were collected from secondary sources that comprised estates' records.

Malaria Incidence[1] at the Estates

Malaria was one of the main diseases encountered on the two large estates for the years 1992 through 1996. At HVE, malaria incidence was, on average, below 11 percent whereas at Chisumbanje, it ranged from 33 to 49 percent, over a 5-year period. The low incidences for HVE are as a result of the comprehensive malaria-control programs instituted by the estate.

Malaria-Control Programs

The two large estates have fairly comprehensive malaria-control programs, amongst other disease-control programs. HVE applies insecticide house- and "winter"-spraying and larviciding for mosquito control. Fish is also used to control mosquito larvae in night-storage dams on the estate. HVE issues prophylaxis (antimalaria tablets) to workers and their dependents. ARDA Chisumbanje estates practice house-spraying and larviciding.[2] Larvicides are applied in the pre-rainy and rainy season when mosquitoes tend to breed. It should be noted that these estates employ full-time Environmental Health Personnel. This marks the importance that the estates attach to the prevention and control of diseases.

Cost of Malaria Control

For the well-documented large estates, the approximate cost of the malaria-prevention programs (after making some assumptions) could be calculated. Table 2 gives a summary of the costs of malaria prevention for the two large irrigation estates, calculated by dividing the actual cost at the estate by the total number of persons on the estate.

At ARDA Chisumbanje, the cost of the malaria-prevention program increased nearly fivefold from 1992 to 1996. This was a result of the annual increase in the cost of chemicals for spraying and medicines. These costs are inflation-driven and could outstrip incomes from irrigation production, as prices of agricultural produce do not increase at the same pace.

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[1]Incidence is defined here as cumulative incidence: the number of malaria cases in a certain period, confirmed by blood slide examination at the estate clinics, as a percentage of the total population in the area served by these clinics at the beginning of this period.

[2]Larviciding: the use of specific pesticides sprayed on breeding sites to exterminate the aquatic larval stages of malaria mosquitoes (editors).

Table 2. Cost[1] of malaria prevention.

Interventions	Hippo Valley Estates			ARDA Chisumbanje		
	1992	1996	5-Year Average	1992	1996	5-Year Average
Insecticide spraying costs (Z$/person/year)	1.63	6.70	3.42	3.50	17.10	10.90
Insecticide spraying costs (Z$/irrigated ha/year)	15.74	20.17	13.52	6.30	32.15	20.12
Insecticide spraying costs (Z$/$m^3$ irrigation water/year)	-	-	-	0.03	0.03	0.03
Control through prophylaxis (Z$/person/year)	n.a.	n.a.	n.a.	n.a	4.47	3.57

n.a. = Not available.

These values can be extrapolated to smallholder irrigation with slight adjustments. At first glance, the costs seem reasonable and affordable, but there are some hidden costs to do with overhead cost, such as supervision, planning, identification of areas to be sprayed, monitoring, and also protective clothing and transport of the spraying team. These could present problems to smallholder farmers because of their limited resources and poor organizational ability.

Labor Days Lost to Malaria Illness

At ARDA Chisumbanje, management indicated that a large number of labor days were lost to production due to illness. Over the 5-year period 1992 to 1996, the average number of labor days lost was 1,551 on a total labor force of around 20,000 workers. These values are not split into disease and worker categories, but as disease statistics at the estate as well as the national level show that malaria contributes 38 percent to disease, it was estimated that the same percentage of these lost days, totaling 590 labor days, was due to malaria. Field workers were more exposed to malaria than the management staff. The loss in labor days translates to about Z$300 loss in production per labor day for cotton pickers or Z$2,800 loss in production per labor day for cutting sugarcane (based on 1996 produce prices). Further to these costs to lost production, in the first days of the disease, there are other costs, such as the cost of replacement labor if the disease takes longer than a day or two and loss in quality due to the possible employment of unqualified and inexperienced replacement labor. This result highlights the importance of malaria-control programs, so as to minimize losses of production. Such losses of production could be disastrous in smallholder irrigation because of the limited production base and resources. Losses in production could have a cascading effect: loss of income, inability to purchase food and a reduced budget to purchase seeds for the next crop. Malaria has thus a wider impact on the welfare of smallholder irrigation communities.

[1]In 1997, US$1.00 = Z$10.00.

Malaria in Small-Scale Irrigation Schemes

Background

Malaria control in smallholder irrigation schemes largely depends on interventions by the Ministry of Health of Zimbabwe. These interventions include insecticide spraying, health education and advice on environmental management. With budgetary constraints, smallholder irrigation schemes are not always targeted. It was hence expected that, if there was a plain association between irrigation and malaria prevalence, it could be found on those smallholder sites, where only limited control activities take place.

Unlike large-scale irrigation enterprises, health data of smallholder irrigation are generally scarce. Furthermore, the standard data of patients who are afflicted with malaria were not detailed enough for an impact assessment study. Records of clinics that serve a smallholder irrigation scheme include a considerable number of patients from dryland farming communities, out of reach of mosquitoes that breed in the irrigation scheme. Data of control measures lack site-specific information. Small-scale irrigation schemes in Zimbabwe are scattered over four ecological regions. Differences in history and purpose of the irrigation schemes, means of water application and ongoing developments contribute to site-specific dynamics that affect the human-ecological balance. This further complicates the effort to provide a picture of "an impact" on malaria from small-scale irrigation. It was decided to make a detailed assessment of a selected number of smallholder irrigation schemes from a cross section of ecological regions. The selected schemes have surface irrigation and, therefore, it was expected that an effect on malaria transmission could be shown.

Data Collection

For such a rapid assessment, readily available data should be used. However, the standard data had their shortcomings: malaria data from rural clinics are subject to misdiagnosis, registration bias and changes in health-seeking behavior that affect reporting. Due to the limited capacity of the regional laboratories, blood slides[1] are, in the best case, taken from one out of five patients. To meet with these shortcomings, additional data were gathered to assist in the interpretation of the clinical-malaria data. Retrospective longitudinal and cross-sectional data, both qualitative and quantitative, were collected and observation and interview techniques were used for risk assessment in the field. Health, hygiene and climate data and environmental, agricultural and community and vector characteristics were obtained for irrigated and nearby dryland farming areas. That way it was aimed to portray the local ecological balance in which malaria transmission is embedded and, hence, to assess a contribution from irrigation to malaria incidence.

Results

Some characteristics and the clinical malaria data of three small-scale irrigation schemes are given in table 3.

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[1]Microscopic examination of blood is the only way to unambiguously diagnose malaria infection. However, in most parts of endemic Africa, people with a positive blood slide may not be clinically ill with malaria (editors).

Table 3. Characteristics and clinical-malaria data for 1992-1996 of three small-scale irrigation communities (IC) and the three dryland farming communities nearby.

Community	Ecol. Region	Altitude	Estimated Prevalence[a] (%)				
			1992	1993	1994	1995	1996
Mushandike IC	IV	900 m	0.3	0.2	0.3	0.4	1
Ngomahuru dryland			0.2	0.0	0.6	1.1	0.5
Mutambara IC	III	700 m	14.3	9.9	11.1	9.9	8.9
Chyamiti dryland			16.3	16.5	9.4	13	19.1
Musikavanhu IC	V	450 m	8.6	17.4	26.2	17.4	41.4
Rimbi dryland			2.9	7.3	14.9	13.7	34.9

[a]Prevalence is estimated here by taking the number of people diagnosed with malaria, based on symptoms and physical examination and dividing that number by the number of persons in the population. The population data for 1993 to 1996 are based on the census data of 1992, adjusted for the local growth rate.

At first sight, we see an increase in the estimated prevalence of malaria with a lowering of altitude. The annual results for the Musikavanhu clinic are higher than in the Rimbi dryland area nearby, suggesting an association between irrigation and malaria. For some years, Mushandike and Mutambara clinics have been showing a higher estimated malaria prevalence than in dryland farming communities living 10-15 km away from the irrigation schemes. Ijuma and Lindsay (2001) suggested, that in an irrigated environment, one vector-mosquito species could be replaced by another with a lesser vectorial capacity thereby causing a reduction in malaria cases at the irrigated site. An entomological survey was not part of this rapid appraisal, but water bodies were checked for the presence of *Anopheles* larvae. Other details helped interpret the above results.

Analysis

The first step was to identify bias and confounding factors in the clinical malaria data from monthly records over a 5-year period. Comparing the fluctuations in estimated prevalence to local circumstances, the trend line could be cleaned from misclassification, registration bias, impact from migration and periodic differences in health-seeking behavior.

It is assumed that the diagnosis in rural health clinics will remain the same throughout the years, showing rather constant underreporting or overestimation of the real number of cases. Hence, instead of considering the number of cases in a month, the trend line would be studied in detail, e.g., a drop in the line in January, followed by a steep rise in March and April coincides with warmer and more humid weather. The effect of climate might be reduced or increased by migration patterns linked to labor demands in agriculture. In the following steps, the trend in estimated prevalence, rather than the number of cases, served as the reference for analysis. Concurrent events were then set off against the trend. This analysis allowed a rapid and adequate assessment of health impacts of irrigation.

Findings

The trend displayed by the health data does not necessarily reflect the transmission pattern in the area. However, data in the local irrigation and dryland clinics on estimated malaria prevalence did reflect the impact from the 1992 drought on malaria and the nationwide epidemic. The estimated prevalence followed the rise and fall of seasonal temperature changes, though the combination of exceptional rainfall and high temperature has likely triggered the 1996 malaria epidemic. This was unusual, as temperature tends to drop with heavy rains. The estimated prevalence of malaria in some irrigating communities was lower than in comparative dryland areas showing the same prevalence trend, while other communities showed equal or greater estimated prevalence compared to dryland results but differed in trend.

When an irrigated area was compared with a dryland farming area, where unmanaged natural water-holding depressions and pools prevail, the results suggested that the scheme's design, operation and management in combination with climatic circumstances played a key role in mosquito-breeding control in both endemic and non-endemic areas. The lack of stagnant water conditions made a scheme less suitable for mosquitoe breeding. Outdoor water harvesting, in other areas notorious for the creation of *Anopheles* breeding sites was not common in smallholder irrigation households.

Concluding Remarks

The assessment of health impacts of irrigation from scarcely documented and biased malaria records requires insight in the circumstances under which the health data were obtained. Rather than the number of disease cases, the movement of the line that connects the estimated monthly malaria prevalence over a number of years, the trend line, could reveal a regularity or explicable irregularities from which a transmission pattern per season can be deduced. The trend can be used as both a reference and a reverse for concurrent events. Multispectral, nonspecific data provide a meaningful instrument to deal with inadequacies in health data as they can reveal triggering factors for local malaria outbreaks in a changing environment. These factors can be addressed in site-specific control measures for short- and middle-term control strategies and health policies.

At the studied estates with large areas under surface irrigation situated in densely populated areas with intensive migration, malaria incidence is kept low through a substantial package of control measures. Malaria prevalence in smallholder irrigation is much more dependent on the nature of the scheme and local circumstances and events that affect the human-ecological balance. Irrigating communities can thus experience lower malaria prevalence than the adjacent dryland-farming communities.

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Literature Cited

Bolton, P. 1994. *Assessing irrigation's impact on the environment.* Bulletin #29. Wallingford, Oxfordshire, UK: Overseas Development Unit and Hydraulics Research Wallingford Ltd.

Chimbari, M.; S. K. Chandiwana; B. Ndlela; P. D. Ndhlovu; R. J. Chitsiko; A. J. Thomson; and P. Bolton. 1993. Schistosomiasis control measures for small irrigation schemes in Zimbabwe. Final report on monitoring at Mushandike irrigation scheme. Report OD 128. Wallingford, Oxfordshire UK: Hydraulics Research Wallingford Ltd.

Hackenitz, E.A.; and A. Senzanje. 1997. *Irrigation and health issues. A profile of surface irrigation in Zimbabwe.* Report for the Ministry of Lands/AGRITEX & European Union, Zimbabwe.

Hunter, J. M.; L. Rey; D. Scott. 1982. Man-made lakes and man-made diseases: Towards a policy revolution. *Social Sciences and Medicine* 16: 1127-1145.

IFAD (International Fund for Agricultural Development). 1998. *Smallholder irrigation support programme – Formulation report*. Working Paper I. Volume II. Report # 0773-ZW: IFAD/Government of Zimbabwe.

Ijumba, J.N.; and S. W. Lindsay. 2001. Impact of irrigation on malaria in Africa: Paddies paradox. *Medical and Veterinary Entomology* 15: 1-11.

National Health Profile. 1998. *Zimbabwe national health profile*. Epidemiology and Disease Control, National Health Information and Surveillance Unit. Harare, Zimbabwe Ministry of Health and Child Welfare, Harare, Government of Zimbabwe.

Oomen, J. M. V.; J. de Wolf; and W. R. Jobin. 1994. *Health and irrigation*. Volume I. ILRI Publication #45. The Netherlands: Institute for Land Reclamation and Improvement.

4. MALARIA AND AGRICULTURE IN THE NETHERLANDS: LAND RECLAMATION, WATER MANAGEMENT AND RISK ASSESSMENT OF A SAFETY CONCEPT

E.A. Hackenitz[1]

It is not tropical countries alone that experience malaria. Countries in the moderate climatic zone, like The Netherlands, have known malaria epidemics in the past. Land reclamation from the sea, initially for agricultural purposes, turned water in the polders into brackish streams, providing a favorite breeding site for the vector mosquito *Anopheles maculipennis atroparvus.* Concurrent developments and interventions in the water-agricultural- and health sector, as well as social changes and progress in science have contributed to the elimination of malaria. After water spilled over the river dikes in the 1990s, a safety concept called 'Rivier*en*land' was developed. The basic principle of the concept was to create space for river water from the hinterland to prevent future flooding. Risk assessment indicates that this safety concept in combination with global warming is unlikely to revive malaria epidemics in The Netherlands.

Introduction

Malaria epidemics occur not only in tropical regions but also in countries with a moderate climate, like The Netherlands where malaria was a public health problem until the mid-twentieth century. Water management and agricultural development contributed to an environment that was conducive to transmission. Malaria was mainly of concern for the health sector; the agricultural and water sectors had their own agenda. The disappearance of indigenous malaria was a result of concurrent and interacting developments, not a concerted effort. A recent safety concept, drawn up after river water spilled over the dikes in the 1990s, brought up the question whether malaria epidemics could return if the water system were to be changed.

Rivier*en*land: A Safety Concept

In the 1990s The Netherlands twice experienced critical flooding caused, so far, by unusual discharge of water in the hinterland river systems of Rhine and Maas. The Netherlands is the delta area of these systems and is popularly called "the drain of Europe." River water spilled over the dikes that were about to be breached. This situation incited the State Water Department to develop a safety concept (TAW 1995). The concept, called Rivier*en*land, started from the principle of

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relying less on the capacity of the dikes through offering more space to the river water such, that people could live in harmony with the new water system. The resulting slowdown of the river current would further stimulate sedimentation and, in the long term, prepare for land reclamation in the delta.

This required a new approach to water management and a different way of thinking about safety among the Dutch population (Ministry of TPWWM 2001, Project Team NW4 1995). Instead of defending oneself against the water through further fortification of the dikes and winning space through land reclamation, one has to relinquish space to water; otherwise the water will sooner or later reclaim space on its own, perhaps in a dramatic matter. The purpose of the new approach in water management is to curb the growing risk of disaster due to flooding and to be able to store water for expected periods of drought in The Netherlands (Ministry of TPWWM 2001).

The concept was basically an exercise in thought. Four major themes were identified for brainstorming: natural systems, quality of life, cost benefit and management and organization (Ministry of TPWWM 2000). Reconnaissance studies were carried out and included a health risk assessment. This study was undertaken against the background of the experience with health impact assessment of flood irrigation in Zimbabwe. This time, a wealth of data was at disposal. Two approaches applied were:

1. Tabular overview, featuring key ecosystem characteristics and preferential and repellent conditions for the transmission of infectious diseases;

2. Review of epidemics that The Netherlands had experienced. Malaria was amongst these (Hackenitz et al. 2001).

The history of indigenous malaria in The Netherlands demonstrates how key interventions and policies in a developing society interacted and effects enhanced one another. The result supports the importance of a comprehensive assessment of policies and interventions in the water and agriculture sectors. The Rivier*en*land safety concept recently got more shape in the initiative "Delta in the Future." The aim of this initiative is to realize widely supported and conscious choices for policies and investments with a bearing on long-term natural and social developments (DidT 2002).

Disappearance of Malaria

Indigenous malaria has been recorded since the parasite was discovered in 1880 (Swellengrebel and de Buck 1938). Malaria-affected areas included mainly homesteads in polders, peat and clay depressions. Malaria outbreaks occurred between May and July. Transmission took place indoors during autumn, when the vector mosquito, *Anopheles maculipennis atroparvus* settled inside the homestead to hibernate. Homestead sharers, infected with *Plasmodium vivax hibernans* or *P.malariae* caused a localized clustering of malaria cases. *P.vivax hibernans* has a dormancy of 6-9 months and could be brought into urban areas undetected. The vector mosquito *An.maculipennis atroparvus* breeds in brackish, slowly flowing clear water and feeds preferably on pigs. At the end of the nineteenth century it was common practice in poor households to keep a few pigs around and inside the house, even in urban areas. Pigs were a source of income generation as well as of food provision. Hygienic conditions in poverty-stricken areas were abject. Farmers kept pigs in sties that were often openly connected to the living quarters. The vector mosquitoes tend to hibernate in the pigsties. The disappearance of indigenous malaria in The Netherlands has been attributed to a number of concurrent and interacting developments between 1850 and 1950 (table 1).

Table 1. Concurrent developments contributing to the disappearance of malaria in The Netherlands.

Key Action		Development
Water management	•	Desiltation of surface water for agricultural purposes
Agricultural modernization	•	Decreasing the number of farmers and increasing the number of pigs per farmer (intensification)
	•	Cleaner, well-lit pigsties with improved ventilation
	•	Increasing the use of fertilizers and pesticides; the runoff pollut ing the surface water
Health interventions	•	General hygienic measures in the homes
	•	Ban on pig-keeping in urban houses
	•	Introduction of hygiene in pigsties and the use of insecticides
	•	Policy: installation of a malaria commission to coordinate the battle against malaria
	•	Targeted residual spraying in malaria-affected homesteads and the attached sties
	•	Application of quinine for malaria patients
	•	Research results: the introduction of window screens as a preventive measure for malaria
Social changes	•	Industrial development: increased labor force, pushing for labor laws by labor unions resulting in the improvement of living conditions
	•	Urbanization and draining of polders for city expansion
	•	Increased use of household detergents and phosphates, dis charged on surface water
Scientific research	•	Discovery of bacteria and parasites: life cycle and transmission mode
	•	Development and application of effective and accessible drugs

This combination of developments was fatal for the vector mosquito's transmission capacity. Its favorite host, the pig, became difficult to access, survival in stables was no longer guaranteed and the water pollution was disastrous for its larvae. The application of quinine phased out the parasite's regeneration cycle through the human host. Further, land reclamation in the Zuiderzee and subsequent changes from brackish water to freshwater diminished the vector habitat. Water councils in Noord Holland reduced the chloride content in polder water, thus turning it into freshwater. The development of the city of Amsterdam led to the complete draining of polder areas around the city, while surface-water pollution from detergents increased with the increasing number of citizens. The incidence of malaria was already at a minimum in the late 1930s. A short epidemic broke out by the end of the Second World War. This has been attributed to dormant *P.vivax hibernans* in the livers of previously infected people. Physical weakness after the hunger winter of 1944, damage to water-management structures, lack of electricity for drainage pumps resulting in the intrusion of salt water, thereby creating ideal brackish-water habitats for *An.m.atroparvus* and migration to urban areas triggered this epidemic. Case-targeted spraying finished this outbreak (Van Seventer 1969). In 1970, WHO declared The Netherlands a malaria-free country.

Considering the environment that was conducive for malaria transmission in the past, the current perspective for land use planning and water management as proposed in the safety concepts “Rivierenland” and “Delta in the Future” and further social, agricultural, and industrial developments as well as global warming will not trigger the recurrence of malaria epidemics. The parasite has disappeared and survival conditions for the vector mosquito are not enhanced by the safety concept.

Conclusion

The history of malaria in The Netherlands is an example of water management, whereby interacting key factors in the ecosystem, concurrent events and social developments make for the presence of disease. The comprehensive assessment applied in the “Rivier*en*land” concept is an effort to identify, anticipate and manage expected (human) ecological changes.

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Literature Cited

Ministry of TPWWM (Ministry of Transport, Public Works and Water Management). 2000. *Flyer: Een troef achter de hand*. Delft, The Netherlands:

Ministry of TPWWM. 2001. *A different approach to water, water management policy in the 21st century.* The Hague, The Netherlands.

Hackenitz, E.A.; M. ter Heegde; and C. Zekveld. 2001. *Rivieren*land*, verkenning van een veiligheidsconcept. 1. Infectieziekten.* (Riveren*land*, reconnaissance of a safety concept: 1. Infectious diseases). Report for the State Water Department.The Netherlands: Ministry of Traffic and Water.

Project Team NW4. 1995. *Ruimte voor water (Space for water)*. The Hague, The Netherlands: Ministry of Transport, Public Works and Water Management.

Swellengrebel, N.H.; and A. de Buck. 1938. *Malaria in the Netherlands.* Amsterdam, The Netherlands: Scheltema & Holkema Ltd.

TAW (Technical Advisory Committee on Water Retaining Structures). 1995. *Under pressure 1 995*. Delft, The Netherlands: Ministry of Transport, Public Works and Water Management.

Van Seventer, H. A. 1969. The disappearance of malaria in the Netherlands. Ph.D. diss., University of Amsterdam, The Netherlands.

DidT (Delta in de Toekomst). 2002. Internet document. http://waterland.net/wvk/proj_delta.htm

5. HYDRAULIC CIVILIZATION AND MALARIA: CHALLENGES FACED BY THE MALARIA-CONTROL PROGRAM OF SRI LANKA

W. P. Fernando[1]

Irrigation and paddy cultivation have been of vital importance throughout the long history of Sri Lanka. Early settlements were established mainly in the dry zone but subsequently depopulation of the dry zone took place, some of the reasons postulated being the spread of malaria and disintegration of irrigation systems due to foreign invasions. Malaria has existed in Sri Lanka from the ancient past, and several epidemics have occurred during the last century. Rainfall is the most important natural factor that influences the transmission and distribution of malaria.
Beside the natural factors, irrigated agriculture and related human activities too have played a very important role in increasing the transmission of malaria in the districts concerned, and also in the creation of new foci of malaria. The author analyzes the problem of malaria related to a major irrigation scheme in Sri Lanka, and it is revealed how both ecological and human factors have been causative in increasing malaria transmission. Special malaria-control measures were carried out by the Anti-Malaria Campaign to minimize the effects of the agricultural schemes. However, it is evident that more effective malaria control would have been achieved if there had been better planning towards health, before implementation of the projects, and also if better coordination between irrigation-project authorities and malaria-control authorities had been established.

Introduction

Agriculture plays a key role in the lives of the people of Sri Lanka. In 1855, a government official working in one of the districts of the country (Badulla District) wrote that "it is possible, that in no other part of the world are there to be found within the same space, the remains of so many works for irrigation, which are, at the same time, of such great antiquity, and of such vast magnitude, as in Ceylon.[2] Probably no other country can exhibit works so numerous, and at the same time so ancient and extensive, within the same limited area, as this Island" (Brohier 1934).

History reveals that the early settlements dating back to more than 2,500 years, were established mainly in the dry zone. The western part of the country too had many settlements. In the dry zone, paddy cultivation seems to have been the main agricultural activity, and the settlements

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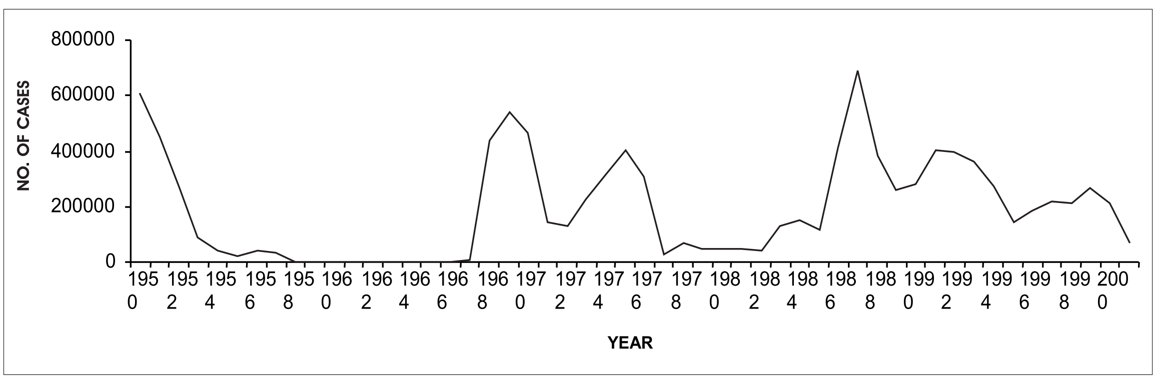
[2]Sri Lanka was formerly known as Ceylon.

primarily established close to the major rivers. Crops were heavily dependent on monsoonal rains but production could be sustained to a large extent through the construction of thousands of small reservoirs, locally known as "tanks." Depopulation of the dry zone began somewhere around the middle of the thirteenth century. A multitude of reasons has been suggested by different historians. The spread of malaria and disintegration of the elaborate irrigation systems due to foreign invasions are mentioned as important causes (Perera 1984). One could visualize the creation of innumerable breeding places ideal for the malaria-vector mosquitoes, that could have resulted from destruction of originally well-maintained irrigation networks. Such an environmental change would have contributed significantly towards increased malaria transmission in the abandoned agricultural systems in the dry zone.

It is likely that malaria existed in the country for centuries, the earliest record of its existence being a map published in 1592 by the Dutch (Plancius). In 1858, a Civil Medical Department was established in Sri Lanka, and since 1877 the administrative reports have mentioned outbreaks of epidemic fever. Organized malaria-control activities were carried out since 1911 (Rajendran and Jayewickreme 1951). The annual number of malaria cases in the country, during the period 1950 to 2001 is shown in figure 1. Malaria epidemics have been recorded throughout the last century, the last major epidemic occurring in 1987 with 676,569 confirmed patients in six districts of the island (Anonymous 1988).

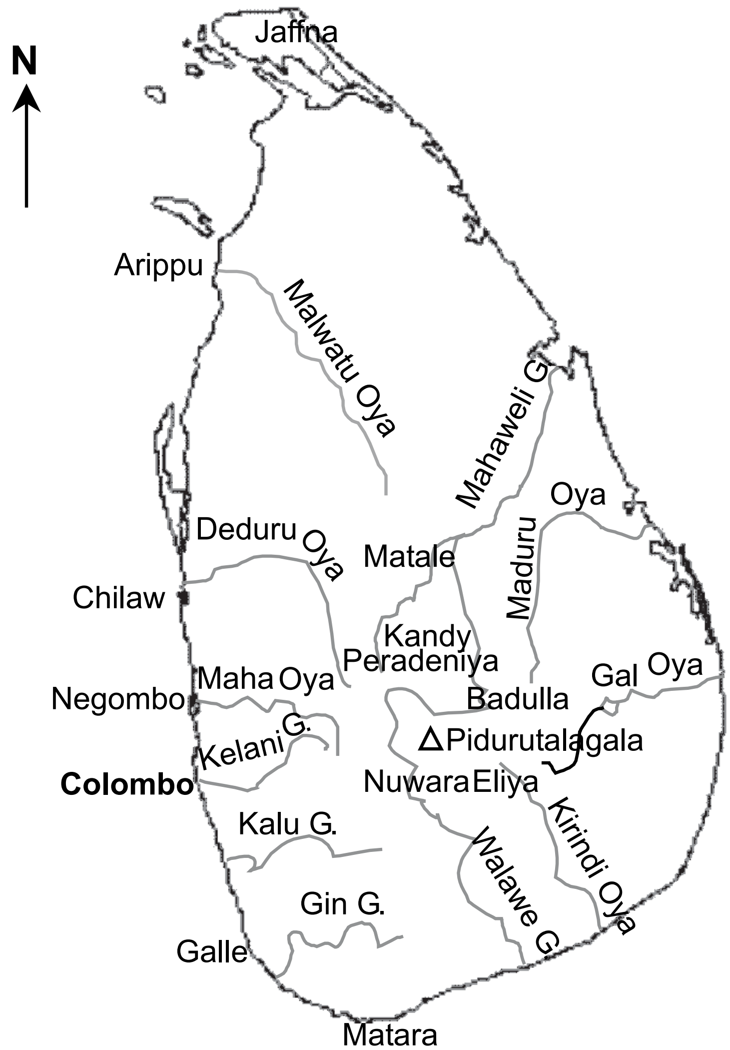
Figure 1. Annual number of malaria cases in Sri Lanka, 1950–2001 (unpublished data Anti-Malaria Campaign, Sri Lanka).



Epidemiology of Malaria in Sri Lanka

The island of Sri Lanka is situated in the Indian Ocean, lying between 5°9' and 9°8' north latitudes and 79°9' and 81°9' east longitudes. It has an extent of approximately 62,705 square kilometers. A mountainous region with a central peak rising above 1,800 meters occupies the center of the island, from which the land gradually slopes towards the sea. Several rivers radiate outwards towards the sea, originating from this central mountainous zone (figure 2). Mahaweli Ganga, Gal Oya, Kirindi Oya and Walawe Ganga are the main rivers that have been harnessed for purposes of irrigated agriculture.

Figure 2. Sketch map of Sri Lanka showing the main rivers.



The island experiences a tropical climate, the temperature and humidity showing only little seasonal variation. In most parts of the country, except the central mountainous zone, temperature ranges between 26 °C and 29 °C and relative humidity is high. Thus perennial malaria transmission can occur in most of the island. Three *Plasmodium*[1] species (*P.vivax, P.falciparum, P.malariae*) were encountered until 1969. However, only *P.vivax* and *P.falciparum* have been recorded since then, with a clear majority of *P.vivax* infections. In 2000, 72 percent of all recorded malaria infections were identified as *P.vivax* and 28 percent as *P.falciparum* (Anonymous 2001). Chloroquine[2]-resistant *P.falciparum* infections were first detected in the country in 1984 (Ratnapala et al. 1984) and resistance to the second-line drug Fansidar was developed in the early nineties. The continued occurrence and spread of drug-resistant *P.falciparum* strains are important considerations in malaria control.

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[1]*Plasmodium* is the protozoan organism that causes malaria (editors).

[2]Chloroquine is the most commonly used and widely available medication to treat malaria (editors).

The main carrier mosquito of malaria in Sri Lanka is *Anopheles culicifacies,* which is a species complex comprising at least four sibling species designated A, B, C and D. In Sri Lanka, sibling B is considered to be the most important and perhaps the only sibling species present (Subbarao 1988).[3] Collections of water in the beds of drying rivers and streams are well known for prolific breeding of *An.culicifacies*. Margins of slow-moving streams and irrigation channels have also been found to be important breeding sites.

The most important natural factor that influences the transmission and distribution of malaria in Sri Lanka is rain, which is associated with the two monsoons: May to September, and November to March (Samarasinghe 1986).

Irrigation and Malaria in Sri Lanka

Besides the natural factors that influence epidemiology of malaria in Sri Lanka, irrigated agriculture and related human activities have always played a very important role. In the recent history of the country, two pioneer large schemes of irrigated agriculture were the Minneriya Scheme and the Gal Oya Scheme, both located in the dry zone. Several factors resulted in an increase of the malariagenic potential and resulted in malaria being a major obstacle to the success of the projects, especially during the initial stages of these agricultural development projects (Samarasinghe 1986). More recently, two major development schemes, the accelerated Mahaweli Development Scheme and the Lunugamwehera Scheme, both of which succeeded in the settlement of a large number of farmer families in land that was made irrigable, experienced malaria as a major public-health problem. An inquiry into the causation of malaria in these schemes reveals that several factors associated with irrigated agriculture increase malaria transmission in such areas. However, this may be minimized by taking timely and adequate preventive measures. The case of the Mahaweli project is discussed below in more detail.

The Accelerated Mahaweli Program

The Accelerated Mahaweli Program is the largest single developmental project undertaken by the Government of Sri Lanka. As a result of a political decision taken in 1977, the life span of the project, which was originally scheduled to take 30 years, was reduced to 5 years. It is a multipurpose project, the major components being hydroelectric power, water storage and diversion for irrigation, downstream regulation and development of physical and socioeconomic facilities to the settlements (Goonasekara 1995). The project harnesses the Mahaweli river, which is the longest river in Sri Lanka, and consists of the four head works projects of Victoria, Kotmale, Randenigala and Maduru Oya; the Minipe Right Bank Trans-Basin Canal Tunnel to Maduru Oya (5.7 km); and the irrigation, settlement and agricultural development of new lands in systems A, B, C, D and H (figure 3 and unpublished data, Planning and Monitoring Unit, Mahaweli Authority of Sri Lanka).

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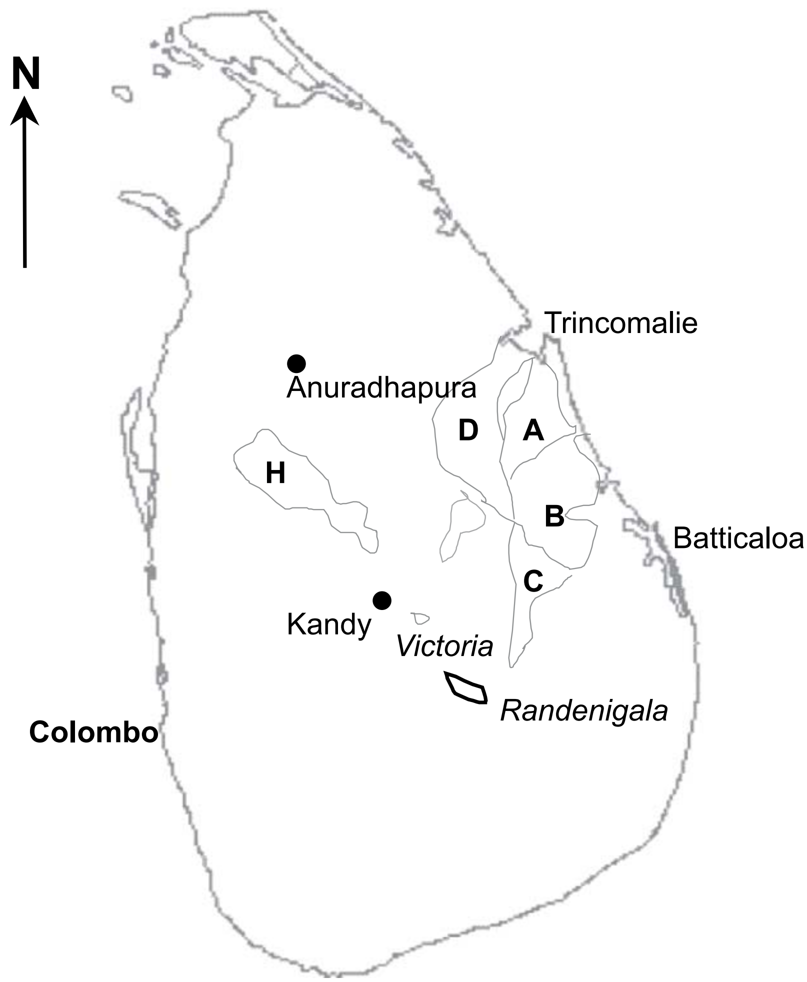
[3]Recently a sub-species type E has been described from Rameshwaram Island between Sri Lanka and the Indian mainland. Surendra et al. (2000) have demonstrated the widespread presence of two members of the *An.culicifacies* complex in Sri Lanka, compatible with species B and E, the latter predominant and having greater vector potential (editors).

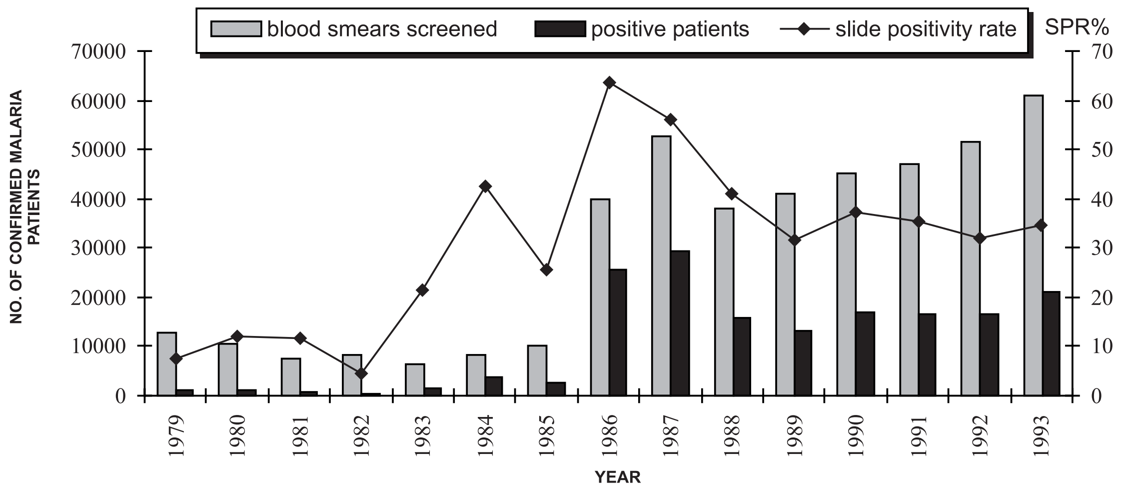
Figure 3. Map showing different systems in the Accelerated Mahaweli Scheme, Sri Lanka.



Malaria Morbidity in System H 1979–1993

A study of the number of confirmed malaria patients detected by four main medical institutions serving "System H" over a period of 15 years beginning from the time farmer families started trickling into the project area (figure 4), and following through the subsequent period of adjustment to the area, and final settlement and engagement in activities involving irrigated agriculture, gives an indication of the magnitude of the malaria problem in the project area.

Figure 4. Malaria morbidity recorded by four main government medical institutions in Mahaweli System H (1979–1993) at Thambuttegama, Talawa, Nochchiyagama and Galnewa (unpublished data, Anti-Malaria Campaign, Sri Lanka). Slide Positivity Rate (SPR) is the percentage of screened blood samples that was positive for malaria parasites.



Malaria Outbreaks in New Foci

Following the construction of the dams at Polgolla and Kotmale, several outbreaks of malaria occurred in the upper Mahaweli region in traditionally non-malarious areas. A malaria outbreak in the hill capital of Kandy was studied by Wijesundera (1988) during May–June 1987. The causative factor has been established as the presence of pool formation conducive to vector breeding, in the riverbed below the Polgolla dam consequent to the low river-discharge rate. In fact, Wijesundera has observed that for most part of the year, the stretch of the Mahaweli river bordering urban areas, lying between the Polgolla dam and the lower Victoria dam, is partially dried up.

A malaria focus in Nugawela close to the Kotmale dam across Kotmal Oya, a tributary of Mahaweli, has been studied by Kusumawathie (1995), who concluded that the creation of *An.culicifacies* breeding sites in riverbed pools below the dam, and the introduction of the malaria parasite by the immigrant population resulted in this focal outbreak. The area had been malaria-free since 1975. This outbreak commenced in July 1990 and continued until February 1991.

Dynamics of Malaria Transmission in Development Schemes with Irrigated Agriculture

Jayawardene (1995) who carried out a research study in a new settlement colony in Mahaweli System C from 1985 to 1987 found a host of factors related to the agricultural development schemes, which contributed to the problem of malaria in the Mahaweli. The observations and conclusions made by the present writer during his work in the Anti-Malaria Campaign, covering different systems of Mahaweli from 1975 to date, are also in full conformity with views held by Jayawardene.

Clearing of vast tracts of jungle land would increase the contact between man and the principal local vector of malaria (*An.culicifacies*), which otherwise prefers cattle blood. The provision of water eventually through a system of surface irrigation channels is an integral part of the Mahaweli Systems. However, seepage of water commonly seen along poorly maintained channels and the stagnation caused by vegetation along the sides of the channels both lead to the creation of breeding sites suitable for *An.culicifacies*. The main crop in the Mahaweli Systems, the rice plant, does not require watering after reaching a certain stage of maturity, making further water flow along channels unnecessary until harvest. Therefore, water-regulating authorities temporarily stop the water issues at this stage. The resulting stagnation of water creates additional temporary breeding sites. Borrow pits were a common site during the initial stages of the scheme, created by removal of earth for various constructional purposes. Collection of rainwater in these pits too was quite conducive to vector breeding.

As land became irrigable the settlement of farmer families followed, unavoidably close to the newly created vector-breeding sites. Many were nonimmune to malaria, coming from traditionally non-malarious parts of the country. They fell victim to malaria in large numbers. The health infrastructure was not well developed at all during the initial stages of settlements, the situation being worsened by the fact that no adequate and satisfactory coordination existed at the time between Mahaweli Authorities and the national malaria-control program. Jayawardene (1995) makes the very important observation that a clear policy and planning for health care in the Mahaweli were lacking.

Malaria-Control Measures in Irrigation Schemes

Intermittent Flushing

Following two trials carried out by the Anti-Malaria Campaign in collaboration with the Mahaweli Development Authorities, it was concluded that a release of 60 m^3/s (2,000 cusecs) of water during for 3 hours at weekly intervals, from the Polgolla dam would significantly reduce the anopheline (and culicine) breeding in the stretch of the Mahaweli river below the dam up to a distance of about 15 km from the dam site (Anonymous 1977). This intervention strategy was carried out regularly for sometime, but conservation of water was of paramount importance to Mahaweli Authorities and, therefore, intermittent flushing had to be abandoned after some time.

Parasite Control and Vector Control

Detection of malaria patients by blood smear examination and subsequent treatment with appropriate chemotherapy was carried out by the government medical institutions in the Mahaweli project areas. The Anti-Malaria Campaign established a network of Voluntary Malaria Treatment centers in collaboration with the project authorities. Weekly chemo-prophylaxis for malaria was administered to farmer families who came from traditionally non-malarious parts of the country, for a period of 6 months after arrival. Residual insecticide spraying of the houses was carried out on a regular basis. Insecticide-treatment of nets was also introduced subsequently.

How Should Future Irrigation Projects Be Handled?

Jayawardene (1995) lists some important considerations in regard to the design and preparation of large water-resources development projects, such as the inclusion of health care as a separate project component, timely planning for health services well ahead of settlement of families, a field-based separate authority unit to be set up prior to the settlement process, and multilateral consultation in which settlers themselves play an important role in decision making.

Based on the experiences gained from the various observations made with regard to the Mahaweli project and others, it is possible to formulate several strategies that would minimize the risk of malaria transmission in future large-scale irrigation projects in Sri Lanka:

- Intermittent flushing to be practiced at dam sites, especially during dry months when the flow of the river below the dam is reduced to a level that would create vector-breeding sites.[1]

- Cement lining of irrigation channels, though costlier, is going to pay in the long run.

- Proper maintenance of irrigation channels, with regular clearing of vegetation on the margins, and regular repair of any cracks or damages on the walls.

- The construction of the houses for farmer families should be the responsibility of the project authorities, so that a house-type that would minimize indoor vector density may be provided.

- A coordinated mechanism between the project authorities and the Anti-Malaria Campaign, to facilitate an effective program of malaria chemo-prophylaxis that would commence before nonimmune persons enter the project site.

Acknowledgements

Sincere thanks are due to Dr. M. B. Wickremasinghe (former Entomologist, Anti-Malaria Campaign, Sri Lanka) for advice and assistance rendered during the preparation of this paper. Help provided by Ms. H. W. D. Shiromanie of the Anti-Malaria Campaign, by way of computer assistance is very much appreciated.

[1]A recent paper by Matsuno et al. (1999) describes the effects of irrigation water releases on malaria mosquito breeding in the Anuradhapura district in detail (editors).

Literature Cited

Anonymous. 1977. *Administration report for the Anti-Malaria Campaign for the year 1976.* Colombo, Sri Lanka: Ministry of Health.

Anonymous. 1988. Administration report of the Anti-Malaria Campaign for the year 1987. Colombo, Sri Lanka. Ministry of Health.

Anonymous. 2001. *Annual Health Bulletin for the year 2000.* Colombo, Sri Lanka: Department of Health Services.

Brohier, R.L. 1934. Ancient irrigation works in Ceylon (Part 1). Colombo, Ceylon: Government Publication Bureau.

Goonasekera, K. 1995. The technical structure of Mahaweli: Limitations and possibilities. In *The Mahaweli: Its social economic and political implications*, ed. H. P. Muller and S. T. Hettige. Ratmalana, Sri Lanka: Sarvodaya Book Publishing Services. pp. 71-94.

Jayawardene, R.A. 1995. Healthcare Management in Mahaweli Project. In *The Mahaweli: Its social economic and political implications*, ed. H. P. Muller and S. T. Hettige. Ratmalana, Sri Lanka: Sarvodaya Book Publishing Services. pp. 205-220.

Kusumawathie, P.H.D. 1995. Human migration and malaria control in malaria outbreaks. A case study of five villages in traditionally non-malarious areas with special reference to the upper Mahaweli Basin, Sri Lanka. M. Phil. thesis, University of Peradeniya, Sri Lanka.

Perera, N.P. 1984. Natural resources, settlements and land use. In *Ecology and Biogeography of Sri Lanka*, ed. C. H. Fernando. Hague/Boston/Lancaster: Junk publishers pp. 453-492.

Rajendran, S.; and S. H. Jayawickreme. 1951. Malaria in Ceylon, Part 1- The control and prevention of endemic malaria by the residual spraying of houses with D.D.T. *Indian Journal of Malariology* 5: 1-73.

Ratnapala, R.; K. Subramaniam; A.M.G.M. Yapabandara; and W. P. Fernando. 1984. Chloroquine-resistant *Plasmodium falciparum* in Sri Lanka. *Ceylon Medical Journal* 29: 135-145.

Samarasinghe, L. 1986. The present malaria situation in Sri Lanka with particular reference to areas where irrigation has been recently introduced. In *Proceedings of the Workshop on Irrigation and Vector-Borne Disease Transmission*, ed. R. Cowell. Digana, Sri Lanka: International Irrigation Management Institute. pp. 4-8.

Subbarao, S.K. 1988. The *Anopheles culicifacies* complex and control of malaria. *Parasitology Today* 4: 72-75.

Wijesundera, M. de S. 1988. Malaria outbreaks in new foci in Sri Lanka. *Parasitology Today* 4: 147-150.

6. ABSTRACTS

Contracting Malaria in the Paddies: An Integrated Approach to Irrigation and Malaria in Northern Côte d'Ivoire

Renaud De Plaen[1]

During the last few decades, the impact of irrigation on the health of rural populations has been drawing increasing attention from researchers in biomedical and social sciences. It has been suggested, for example, that the construction of water reservoirs and drainage can lead to an increase in the number of breeding sites for mosquitoes, affect mosquito density and, therefore, influence the transmission intensity and prevalence of malaria.

Most research on the potential impacts of irrigation on malaria has been based on two approaches: a classical epidemiological approach focusing on human-vector contacts and a culturally oriented one based on the influence of sociocultural factors on health behaviors.

The author's argument is that these two approaches are insufficient to explain the impact of irrigation projects on malaria and need to be complemented by alternative, more systemic approaches. One such approach is the "ecosystem approach to human health" that considers the impact of irrigation programs on the natural environment and socioeconomic organization of rural populations. While human-vector contact is one of the factors included in the approach, it also investigates how irrigation affects various aspects of the daily life of farmers and how such transformations, together, affect health behaviors and malarial prevalence.

This approach is applied to a case study in Northern Côte d'Ivoire. Results demonstrate that spatial variations in malaria prevalence between communities involved in irrigated agriculture and others, which are not, cannot be explained by human-vector contacts alone but require a broader understanding of the ways irrigation affects the farming system as a whole, socioeconomic organization and, especially, gender relations.

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Malaria and Schistosomiasis Risks Associated with Surface and Sprinkler Irrigation Systems in Zimbabwe

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A comparative assessment of the malaria and schistosomiasis risks associated with surface- and sprinkler-irrigation systems in Zimbabwe was carried out. The risk assessment of the two diseases was done in accordance with the three standard components of the Health Impact Assessment: community vulnerability, environmental receptivity and capability of health services to respond to malaria and schistosomiasis. Statistics of the two diseases at one Health Center within an irrigation scheme and another outside the scheme were used to determine the disease trends. The study indicated that both malaria and schistosomiasis are problems of irrigation schemes. Sprinkler systems were apparently associated with malaria while surface schemes were more associated with schistosomiasis. This observation was attributed to poorly maintained infrastructures and inadequate leveling in the case of sprinkler schemes, which promoted mosquito-breeding sites within the fields, and to poorly draining structures in the case of surface-irrigation schemes, which created snail-breeding sites. It must be emphasized, in particular for sprinkler schemes, that poor maintenance of infrastructure accounted for more disease-promoting features than the engineering designs per se. While curative measures at Health Centers within the schemes were optimal, preventive measures were weak and there seemed to be a lack of appreciation of the special health problems presented by small-scale irrigation schemes. Recommendations on possible safeguards and mitigating measures were made.

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Incidence of Malaria in Irrigated Areas of Raichur District, Karnataka: A Comparative Analysis

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Malaria is one of the major diseases caused by the *plasmodium* parasite, transmitted by the infective female *Anopheles* mosquito. *Plasmodium vivax* and *P.falciparum* are the two species of malaria parasite prevalent in Karnataka, India. The most problematic districts for malaria in Karnataka are Bijapur, Raichur, Kolar, Bellary and Mandya, together contributing 63 percent of malaria cases and 75 percent of *P.falciparum* cases during 1997.

In Raichur, the incidence of malaria has increased in recent years. The number of patients identified positive (both *P.vivax* and *P.falciparum*) in 1994 was only 5,396 while this increased to 12,194 in 2000. In the Raichur district, the rain-fed areas of Deodurga and Lingasugur had higher numbers of malaria cases than the irrigated areas of Raichur Block, Manvi and Sindhnur (see table below).

The lower number of malaria cases in irrigated areas compared to that of rain-fed areas is mainly attributed to the application of plant protection chemicals, which is more pronounced in the case of paddy and cotton. Once the pesticide is diluted with irrigation water, the multiplication of mosquitoes is decreased considerably. In rain-fed situations, there is little scope for water being mixed up with pesticides. Consequently, multiplication of mosquitoes is greater and, hence, there are more patients tested positive for malaria.

Block	Main Crops	Percentage Irrigated Area	Number of Malaria Patients (1994-2000)
Deodurga	sorghum, millet	3	2,507
Lingasugur	groundnut, cotton	8	5,466
Raichur		28	842
Manvi	paddy, sorghum, cotton	33	616
Sindhnur		57	403

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Malaria Vectors in Relation to Irrigation in an Area of the South Punjab, Pakistan

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The decreasing effectiveness of conventional methods of malaria-vector control has led to the reemergence of environmental management as a possible alternative strategy for the reduction of mosquito vector-breeding sites and health risks associated with them. The design and operation of irrigation systems can be modified to prevent the proliferation of malaria vectors and reduce malaria transmission. The objectives of the present study were to assess the importance of irrigation-system components in the generation of malaria vectors, as a first step to identifying and designing environmental-management interventions for the control of disease vectors. All surface-water bodies in and around three selected villages along an irrigation distributary canal in Haroonabad, Southern Punjab, Pakistan, were surveyed on a fortnightly basis for *Anopheles* mosquito larvae from April 1999 to March 2000 as part of an investigation into the potential linkage between irrigation and malaria transmission in Pakistan. The selected villages reflected a continuum of habitats from severely waterlogged to desert conditions. The samples were characterized according to exposure to sunlight, substratum, presence of vegetation, fauna and physical water condition (clear/turbid/foul). Also water temperature, dissolved oxygen (DO), electro-conductivity (EC) and pH were noted *in situ*. All the potential malaria vector species showed marked seasonal abundance in the three villages, with the peak numbers from August to December. However, species composition differed between the villages. The predominant species were *An.stephensi* in the waterlogged village and *An.subpictus* in the desert village. Overall, the results indicated that irrigation-related sites in South Punjab do support the breeding of anopheline mosquitoes, including malaria vectors. The major malaria vector in Pakistan, *An.culicifacies*, occurred at relatively low densities, mainly in irrigated and waterlogged fields. Important parameters determining the occurrence of anophelines included physical water condition and presence of predators. No relationship could be detected between mosquito larvae and water temperature, DO, EC, and pH. In South Punjab rainfall is low, which makes it possible to reduce vector breeding through water management, as all *Anopheles* breeding sites are directly or indirectly linked with the extensive canal-irrigation system.

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Irrigated Agriculture and Exacerbation of *P.falciparum*-Dominated Malaria in the Thar Desert, Northwestern Rajasthan

B.K. Tyagi,[1] J.R. Sharma[2] andS.P. Yadav[3]

The Indira Gandhi Nahar Pariyojana (IGNP) extensive irrigation scheme in the Thar Desert provides an excellent model for the study of exacerbation of *P.falciparum*-dominated malaria, vector breeding and, more importantly, the research into how water management can help eliminate this disease in a land fast converting to an hyper-endemic region for malaria.

Altogether 32 villages in three different irrigation-impacted districts, *viz*., agriculturally advanced and paddy-growing Sri Ganganagar (16 villages), recently irrigated Jaisalmer (6 villages) and nonirrigated Jodhpur (10 villages) were investigated. In nonirrigated villages, malaria transmission was essentially effected by *Anopheles stephensi,* breeding in household and community-based drinking water reservoirs. *An.culicifacies*, a recent entrant, with irrigation, in the interior of the desert, which breeds copiously in varied habitats, dominantly transmitted malaria, particularly of the *P.falciparum* type, in the IGNP irrigated villages. Altogether 8 species were collected from Sri Ganganagar and Jaisalmer, with both *An.culicifacies* and *An.stephensi* present there. Following a mass blood survey in late 1993 in the IGNP villages with irrigation-intensive cropping (*P.vivax* 11%, *P.falciparum* 89%) and in the nonirrigated villages (*P.vivax* 17%, *P.falciparum* 83%), fever surveys conducted in 1993-94 revealed a higher blood-sporozoite rate (32.3%) in the irrigated than in the nonirrigated villages (25.5%). The most alarming feature was, however, the higher proportion of *P.falciparum* in the IGNP villages (77%) compared to the nonirrigated villages (17%), and the two distinct peaks in March-April and December-January. Also, the irrigated villages predominated in gametocyte carriers (17.8%) when compared to the nonirrigated villages (8.3%). In both types of villages 73.7% of all positive cases originating from children less than 14 years of age, which indicates a substantial risk to this vulnerable group of the population. The latest study done in Jaisalmer in 1999 further confirms these results.

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Irrigated Agriculture Disrupts Eco-Life-Line: A Paradox

Soorya Vennila[1]

Irrigation in India has had a history extending over millennia. The state of Tamil Nadu can claim some of the oldest examples of irrigation works in the country where three main modes of irrigation, from rivers, tanks and wells are practiced.

South Arcot district in Tamil Nadu is bestowed with the three modes of irrigation practices with remarkably high intensities over large areas. Apart from that, South Arcot is found to be one of the leading districts to get good rainfall. The backdrop of irrigation in this district is wide-ranging and complex, which contributes to growth, diversification, trade and employment.

In the village of Pacharapalayam in South Arcot, where farming is the most important occupation, four major conditions contributed to the proliferation of mosquitoes:

1. The indiscriminate fragmentation of land.

2. Lack of proper irrigation infrastructure and consequent flooding.

3. Less distance between irrigation infrastructure (irrigated farms and reservoir) and residence.

4. The stagnation of water used for livestock (bathing, washing and cleaning) because of the improper drainage system.

This paper aims to analyze in detail the reasons for the rampant growth of mosquitoes and its implications on irrigated agriculture and how irrigated agriculture, in turn, affects the eco-life-line in South Arcot district with special reference to malaria.

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Best Practices to Control Malaria in Irrigated Agriculture: The Case of Improved Traditional Irrigation Schemes in Tanzania

Remigius Ignace Rushomesa[1] and Jacob Ndonde[2]

Planning for the development of water resources for agricultural production is of paramount importance to sustainably utilize water resources with minimum effects on human health. In the past, irrigation projects did not fully address environmental impacts and, as a result, human health deteriorated a great deal due mainly to increase in water-borne, water-related and water-oriented diseases.

The Tanzania National Irrigation Development Plan (NIDP) considers rehabilitation (improvement) of traditional irrigation schemes as number one priority. Most of these schemes suffer from

- lack of improved water abstraction structures
- poor water conveyance systems
- poor water management practices
- lack of health and sanitation education

In Tanzania, malaria, (so far) the leading killer disease, is very much associated with water-resources development projects, and irrigation is of no exception. Improvement of traditional irrigation schemes offers an excellent opportunity to incorporate remedial measures to combat malaria through better design of irrigation canals, improved drainage systems and better water-management practices.

The paper attempts to give an account on the lessons learnt in Tanzania with regard to the ongoing improvement of traditional irrigation schemes with particular emphasis on the war against malaria. To effectively fight malaria, experts from different sectors need to actively collaborate in the day-to-day activities with the active involvement of the communities. The paper also discusses mitigation measures that have been applied in the course of carrying out irrigation activities.

It concludes by underscoring the important role of water towards increased irrigation output. However, for irrigation development to bear the intended fruits, there is a need to go for inter-sectoral planning and management of irrigation projects, which will ensure that best practices are in place in an effort to control malaria in irrigated agriculture.

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Ecological Control of Malaria Mosquito Larvae at the Rehabilitation of Irrigation and Drainage Systems

Konstantine G. Bziava[1] *and Irakli G. Kruashvili*[2]

The modern concept of ecological methods to control larvae of malaria mosquitoes includes not only biological techniques, such as the introduction of larvivorous fish in reservoirs and the destruction of aquatic vegetation, but also a number of methods using naturally limiting factors of a hydro-chemical and hydrological character. Proposed measures of a hydrological mode are aimed at:

- periodic watering of agricultural crops combined with obligatory complete drying of the soil after each irrigation
- intermittent irrigation of rice fields and other fields with artificial water supply
- changing the water table in reservoirs
- periodic drawdown of water in currents
- destruction of places where the mosquitoes breed (fine rehabilitation works)
- anti-malaria measures in the construction of reservoirs and the realization of hydraulic engineering works

In the last decade, a lot of attention was given by the Georgian scientists to the development of anti-malaria requirements at the implementation of large hydraulic engineering and irrigation works. The following measures were added to the basic requirements of hydraulic engineering works:

- sufficient drainage of mosquito breeding sites and correction of micro-relief to ensure the absence of stagnant water on the area intended for cultivation
- absence of stagnant water in all types of channels
- prevention of formation of channels, holes, reserves and other depressions, where water may stand and accumulate
- absence of water seepage through bores after sufficient time for their silting

In this, presentation the separate anti-malaria measures are considered in detail, with an emphasis on the different types of earthen works connected to the implementation of rehabilitation work, such as digging ponds and reservoirs, constructing roads or building structures.

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Subsurface Drainage: A Tool to Control Malaria in the Chambal Command Area

L.K. Dadhich,[1] Savita Gupta[1] and C.M. Tejawat[2]

There was a massive resurgence of malaria in both the normal *P.vivax* type and the *P.falciparum* variety in India in mid-1970s. In 1976, the number of malaria cases rose to a peak of 6.4 million, including 0.7 million of the *P. falciparum* variety with 59 deaths. The upsurge was controlled by the mobilization of extraordinary resources under the modified plan of operation launched in 1977. As a result, the large numbers of malaria dropped to 2.1 million by 1984. Since then, however, the epidemiological situation has not shown any great improvement. It seems to have reached a plateau, which is causing concern. Almost the entire population of India (95.9 percent) is now deemed to be under malaria risk. This statement was true for the Chambal command area in Rajasthan as well. The installation of subsurface drainage in 1992-98 however, changed the scenario and a decrease in the spread of malaria is observed.

Subsurface drainage has been recognized as the basis for any long-term success in tackling the problems of waterlogging and soil salinity. Successful efforts made in recent years in the Chambal command area of Rajasthan helped in controlling the problems of mosquitoes causing malaria. The health benefit of subsurface drainage is the decrease in the amount of standing water used as a breeding habitat for mosquitoes, caused by the reduction of waterlogged areas.

Mosquito-borne diseases are reduced in Chambal after the installation of subsurface drainage through the RAJAD project sponsored by CIDA. The paper discusses the potential positive impacts of subsurface drainage in the Chambal command area in relation to the spread of malaria. The paper also presents a comparison between the annual parasite index, the slide positive rate and the slide *falciparum* rate in the population. The annual parasite index, which rose to 14.18 in 1989, decreased considerably to 2.18 after the installation of subsurface drainage in the Chambal command area during 1993-2000. Similar results were obtained for the other indicators.

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The Effect of Plant Spacing and Intermittent Irrigation of Different Varieties of Rice on the Productivity of the *Anopheles* Mosquito

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A split-block design was used to compare the mosquito productivity under four varieties of rice, exhibiting differences in height and the number of tillers produced. *Afaa mwanza* and *Subarmati* were improved traditional types whilst IR54 and RD23 were high-yielding varieties, originating from the International Rice Research Institute, Philippines. Effects of permanent versus intermittent irrigation and plant spacing on mosquito productivity were also assessed. Overall, *Afaa mwanza* was the tallest, *Subarmati* and RD23 were intermediate whilst IR54 was the shortest. The high-yielding varieties produced the highest number of productive tillers compared with the traditional types. Results of drop-net collections of mosquitoes showed large variations in the numbers of adult *Anopheles gambiae sensu lato* produced weekly. There was an inverse relationship between the height of rice plants and the number of *An.gambiae s.l.* produced from week 1 though week 11. The highest peak was produced in week 1. There was no significant difference between varieties, but 20 x 25 cm spacing between rice plants was significantly more productive than 20 x 20 cm spacing. *An.pharoensis* showed a positive association with the height of rice plants, and produced a peak towards the end of the sampling period. Intermittent irrigation was associated with higher mosquito productivity than permanent flooding, and this was attributed to the effect of small pools created by water drying out from the field. It was not possible to drain all the water from the fields. The findings are discussed in the context of rice irrigation and malaria transmission.

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Can Irrigation Water Management Be Used as a Tool for Malaria-Mosquito Control? The Case of the Office du Niger in Mali

E. Klinkenberg,[1] F. Huibers,[2] W. Takken[3] and Y.T. Touré[4]

A field study was carried out in the large-scale rice irrigation scheme of the Office du Niger in Mali to investigate the relation between malaria mosquito larval development and differences in field-irrigation practices, such as the water depth in the field, irrigation application and irrigation frequency. The main aim was to find out if water management can be used as a tool for vector control. The results showed that the main malaria vector in the study area, *Anopheles gambiae sensu lato*, develops predominantly in the first 6 weeks after transplanting of rice. During further vegetative growth of the rice a succession of anopheline species was observed. This succession was related to a decrease in light intensity reaching the water surface. The results also showed that minor differences in water management already resulted in noticeable variations in larval development with respect to larval densities and species composition. Due to incomplete drainage after harvest, *An.gambiae s.l.* breeding was soon reestablished in fields where small pools of water were retained. For the Office du Niger, two possible options for mosquito control through water management could be defined. First, the strict adherence to an agricultural calendar in which a rotation of planting in large blocks is foreseen. This could help interrupt the observed continuous breeding of *An.gambiae s.l.* made possible by the present practice in which neighboring fields are planted subsequently. A second useful improvement would be to strive for an early and complete drainage of the fields after harvest, as remaining water in the fields forms an ideal habitat for *An.gambiae s.l.*

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Transmission of Malaria and Its Consequence on Agricultural Productivity: Evidence from a Major Irrigation Project in Karnataka, India

G Mini[1] and Amalendu Jyotishi[2]

Though the interest in irrigation and associated health-related problems is growing, very few studies have been conducted on the causality and consequences of these problems. Vector-borne diseases in general and malaria in particular are identified as increasing in major irrigation-project areas due to poor management of water as a result of both exogenous and endogenous factors. Keeping this in view, the objective of this paper is to examine the water- management practices and transmission of malaria in a major-irrigation project in India.

In the present paper we attempt to develop a conceptual framework of understanding the transmission of malaria due to irrigated agriculture from an institutional economics perspective. The framework of institutional economics provides insight into factors such as how different stakeholders interact, negotiate and make decisions, which is often left out in conventional economics.

Evidence from Tungabhadra, a major protective irrigation project in Karnataka shows that the existence and functioning of water user associations (WUAs) play an important role not only in enhancing agricultural productivity but also in reducing the transmission of malaria due to efficient water-management practices. This situation is contrasted with one where there are no formal institutions to govern water use. In the former case, the WUAs take over the distribution of water. In the latter case, control continues to lie with the agency, both technically and institutionally. Economic losses resulting from malarial attacks are captured in terms of human-days lost (agricultural productivity loss) and cost of malarial treatment (health cost). Empirical analysis as reflected from the case study shows a positive relation between ineffective water-management practices and transmission of malaria. Finally, the paper concludes emphasizing institutional solutions to health problems and discusses the rational water-management approaches that will ensure not only economic but also larger social (equity) and environmental (sustainability) goals.

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Malaria-Induced Production Cost (Loss) in Swamp Rice Cultivation in Southeastern Nigeria

Obot Ekpo Essien[1] and Mfon Ekong[2]

The case of the Enyong Creek Swamp catchment in southeastern Nigeria was studied, where rice farming, both rain-fed and irrigated, is undertaken by a population of 168,000 in 14,001 households (8 percent being riparian rice farmers). Although the swamps are economically resourceful, the farmers' household members constituting the family labor force, are often too sick, too ill-fed and too exhausted by intensive labor to earn enough to buy medicine, food and education and to obtain enlightenment, knowledge and skill to improve their living standard. Household labor here comprises men, women and children, an average of 5 persons and hired labor. The bacterial and parasitic infections were assessed by an analysis of water quality and an examination of the spleen.[50] Malaria, measles and gastroenteritis, in that order, were found to pose the most serious community-health problems. The average number of episodes of malaria per household was 6 per year. This area can be described as a hyper-endemic area for malaria having an average splenic rate of 24 percent.[51] The cost implication of these malaria episodes is a financial loss to household investments; a sensitivity analysis of cost-up-and-benefits-down 10 percent indicated a highly reduced benefit to increased cost. The cost assessment comprised wage rate or missed mandays per malaria episode; transport to second tier referral at 8-60 km; the mortality rate; the willingness to pay; the variable cost (added value of productive activities) and opportunity cost.

Their sum was higher than the expected 57 percent increase of average farm income from the mainly agronomic-intensification program and stifles income security and expansion. This suggests intensifying farmer-targeted health care, such as preventive sanitation and well-planned farm settlements with health posts for large irrigated swamp farms in the humid tropics.

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Economic Cost of Malaria Attacks in an Agricultural Area of Burkina Faso (West Africa)

Robert T. Guiguemde,[1] N. Coulibaly,[1] J.B. Ouédraogo[1] and A.R. Gbary[1]

The economy of Burkina Faso is mainly based on agriculture. This country is endemic for malaria, a disease that is mostly affecting children under 5 years, but causes lost workdays of mothers for taking care of their ill children. We undertook this study to assess the economic cost of malaria attacks in an area of Burkina Faso where the main activity of people is agriculture.

The study took place in three villages having health centers where microscopic diagnosis of malaria can be performed for all patients attending these centers. When malaria was confirmed, its direct costs (fees for consultation, microscopic examination, medication and transportation) and its indirect costs (cost of lost workdays for farming) were assessed. The assessment of the indirect cost, the more difficult one, was done according to a formula we developed and that takes into account 7 variables, which are age of patient, degree of invalidity, duration of invalidity, duration of illness, profession, income and percentage of income lost.

The average duration of uncomplicated malaria was 4 days. The mean cost of a malaria attack was US$11.7, comprising $8 direct costs and $3.7 indirect costs. In addition to these costs of the illness, the costs for preventive measures, such as bed nets and mosquito sprays, must be considered to assess the total impact of malaria on the income of the rural people.

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Measuring the Economic Impact of Malaria in Irrigated Agriculture: A Case Study of Northern Guinea Savanna, Nigeria

Oyenike Oyenuga[1] and R. M. Hassan[2]

This study seeks to assess the social and economic impact of malaria on farming households and on agricultural productivity in the northern Guinea Savannah of Nigeria. A survey of 150 farming households was conducted to collect information on malaria-control practices, malaria and farm work and other information needed. Compared with other regions in Nigeria, the northern Guinea Savannah region produces more agricultural products because of its endowment of arable land. However, due to the arid climatic conditions, irrigation is a crucial input in the production process. The results from the study show that the estimated economic cost of malaria treatment per household is $ 2.15 for mild, $ 4.85 for moderate and $ 19 for severe cases of malaria. The average number of sick days was estimated at 1, 4 and 7, respectively, for the three groups. The cost of protection against malaria for households was estimated at an average expenditure of 12, 5, 10, 14 and 9 percent of their annual income on insecticides, drugs, nets, coils, and local herbs, respectively.
This study could not derive estimates of the loss in productivity using the production function approach because of lack of data. Alternatively, the wage rate method was used to measure productivity loss. The results show wage losses of 5, 22 and 35 percent of the family household annual income for mild, moderate and severe cases, respectively. Therefore, it can be concluded from this study that farmers lose a significant percentage of their annual income to malaria. Accordingly, the result suggests that malaria control programs are worthwhile and justified in terms of avoided losses in social welfare in irrigated farming in Nigeria.

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