Relationships between rice irrigation, mosquito breeding, malaria, water losses and reduced rice yields: research from the Usangu plains, Tanzania

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Abstract

This paper presents a case study in Usangu Sub-basin, Tanzania, investigating the relationships between irrigation water management, rice productivity, and malaria incidence. The information was gathered for two paddy growing seasons from two types of irrigation systems namely large/modern and smallholder irrigation systems. The number of days that water spent in the fields and their respective daily depths were recorded for each season. Further, the annual volumetric water use for different irrigation systems were monitored from three selected sample fields. The average rice yields were then computed from each trial field and the productivity of water in Kg of paddy per cubic metres of annual volumetric water use was worked out. On the other hand, malaria incidences were recorded for two different age groups in the area with their respective occurrence period. The relationship of malaria incidence and its pattern to peak activities in the fields were used to assess the loss in rice productivity. The result suggests that there is a significant contribution of high depth flooding technique (up to 25cm), to increased malaria incidences, water losses and low productivity of irrigated water in the study area. A loss of up to 8% in rice productivity was estimated to occur per single malaria attack in wet season. In addition the findings suggest that about 40% of the water could be saved from large irrigation systems through intermittent irrigation and an obvious reduction in malaria breeding and without necessary affecting the rice productivity.

Keywords: Usangu Sub-basin, irrigation water management, rice productivity, productivity of water, malaria incidence

1. Introduction

During the past two decades, there has been an increasing awareness of adverse effects on health accompanying the development of various types of water resources, particularly irrigation projects (Tarimo, 1998). Of all water-related diseases, malaria is probably the most commonly known disease. Malaria is essentially a chronic disease in the tropics. Apart from its classic fevers, malaria is characterized by high infant mortality, stillbirths and abortions; with the enlargement of the spleen; and the predisposition of its victims to other infections (Tarimo, 1998).

In Tanzania malaria is one of the water-related diseases with the highest prevalence in all irrigation schemes. Co-existence of irrigated agriculture and malaria has been reported in different irrigation schemes in Tanzania including the Modern (NAFCO) and traditional (improved and non improved) irrigation schemes in Usangu plains (ISID, 1994). Irrigated fields encourage the multiplication of mosquitoes, a vector for malaria. This is particularly so in Usangu where irrigation is mainly continuous flooding and further neglect of some irrigation canals leads to standing water bodies and increased growth of weeds. In an investigation on the potential linkages between irrigation and malaria transmission, Herrel *et al*. (2001) found a

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significant association of waterlogged fields with the abundance of *Anophles* species. He further noted that malaria vectors of the *Anopheles culicifacies* complex occurred at relatively low densities, mainly in irrigated and waterlogged fields. Because all the immature stages of mosquitoes i.e. eggs, larvae and pupae are all aquatic, ISID (1994) ascertained that flooding the fields, a practice common in Usangu plains provides excellent environments for their survival and eventual development into adults that are able to transmit malaria.

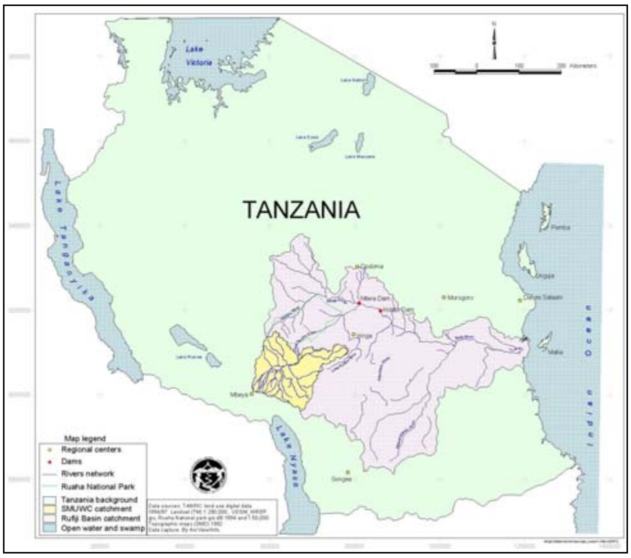
The irrigation methods, management and land preparation seem to be more important for controlling water vector borne diseases and increasing the productivity in irrigated fields. Irrigation methods such as alternate wetting and drying can significantly reduce incidences of malaria and increase productivity of water. In the Philippines, water disease vectors were reduced from 200 to less than one per square metre and the rice yield increased by over 50 percent as a result of intermittent irrigation techniques (ISID, 1994). There are possibilities to reduce *anopheline* breeding through water management, as the larvae develop mainly in water bodies that are directly or indirectly connected to extensive canal-irrigation systems (Herrel *et al*., 2001). Shallow water areas, especially those with vegetation growth are regarded as suitable conditions for malaria vectors (Tarimo, 1998). Rice irrigated fields with ponding water therefore encourage enhanced vector-dynamism for malaria.

The first disease killer in Mbarali District (the key district for Usangu) is Malaria and accounts for about 53% of all deaths occurring in health facilities while morbidity account for 47.5% of all outpatient disease (OPD) cases (HMIS 2000). The problem of malaria is more serious when it afflicts children under-five (even though the number of deaths for under-fives may be lower when compared to above five years age group). Ill children impose a social cost because women are more responsible for childcare, obligating them to spend much more time caring. However, it is believed the malaria data from Mbarali District are highly underestimated because they are taken from formal health-facility records. In contrast, many patients are nursed at home and if death occurs at home these statistics are not recorded accordingly. This paper reports findings of a two seasons (1999/2000-2000/2001) study on irrigation water management and their influence on malaria and water productivity in irrigated fields in Usangu plains.

2. Methods

Location of the study

The study was conducted in Mbarali District, in the Usangu plains, located in the South-West Tanzania (see Figure 1). The study area is on the upper part of the Rufiji basin, the largest river basin in Tanzania. The area is situated at 1040 metres above sea level. The general climatic pattern is tropical wet-and-dry characterised by short periods of rainfall, moderate to high temperature, low wind speeds, and high humidity of the air and the absence of cold season. The mean annual rainfall in the Usangu plain is 669mm. The mean monthly temperature ranges between 21°C in July and 26°C in November and the relative humidity varies from 50% in October to 80% in January to March. The daily hours of sunshine range from about 6 hours (March/April) to 10 hours (July/October). The daily mean wind velocity at study location is estimated at 237 km/day. *Alfisols* (KRIP, 1992) are the main soil types found in the study area.



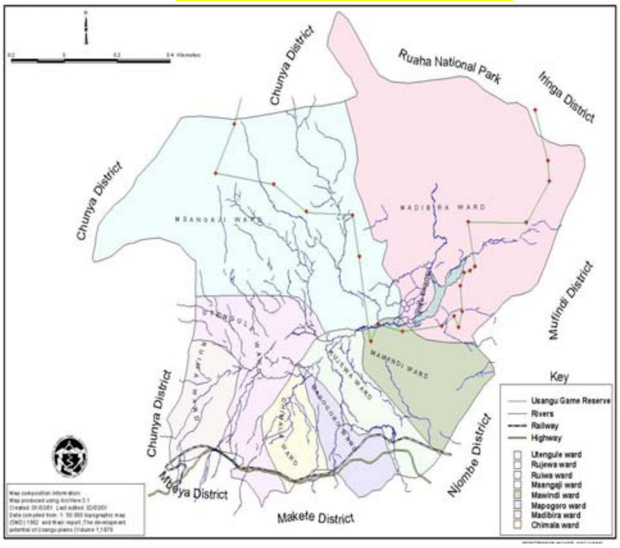


Figure 1: Map showing location of the study area (*After: SMUWC, 2001*)

Methodology

The on-farm experimentation was applied to monitor irrigation water in selected paddy fields of large/modern (NAFCO) farms, improved and traditional irrigation systems in the study location. This included mapping the number of days water spent in rice fields during the entire crop-growing season. Further, their respective daily water depths and the annual volumetric water use for different irrigation systems were monitored. The average rice yields were then computed from the total annual volumetric water consumed by the crop. The malaria data incidences from six wards were collected from Mbarali district hospital between two age groups (< 5 years and ≥5 years) with their respective occurrence period during the rice production activities in the study period. Relating the occurrence of malaria incidence and peak activities in the fields was used to assess the loss in productivity to farmers. Using the pair wise ranking it was possible to estimate the likely losses induced by malaria per season per household in the study area.

3. Results and Discussions

Malaria cases

Figures 2 and 3 show total malaria cases for the two age groups and in some sampled wards of Mbarali district. The malaria cases for underfives are less compared to cases for five and above years. This is attributed to increased mosquito bites while in paddy fields for peoples involved with farm activities in addition to night mosquito bites in their houses. Also because of limited resources, many preventative measures are directed towards children at household level. The Malaria cases are high in Rujewa, Madibira, Mapogolo and Utengule-Usangu wards compared to Ubaruku (*not indicated in the map*) and Mawindi wards. The location of Ubaruku ward as a business centre and probably with the use of Malaria control measures such as use of treated net may have resulted to low malaria cases. In Mawindi ward irrigation is not extensive because it is located in a low-density river network relative to other wards. The Malaria variations does not show a defined pattern in each ward for the different years being relative higher where intensive irrigation exists with the exception of Mawindi ward in 2001 compared to location with low or no irrigation intensities.

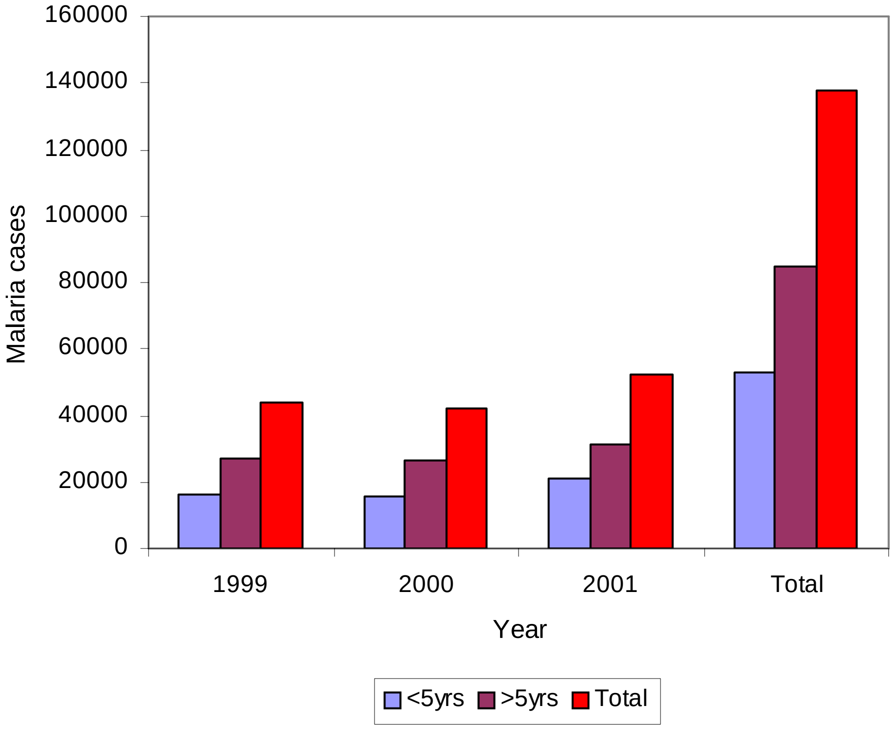


Figure 2. Malaria distribution between age groups

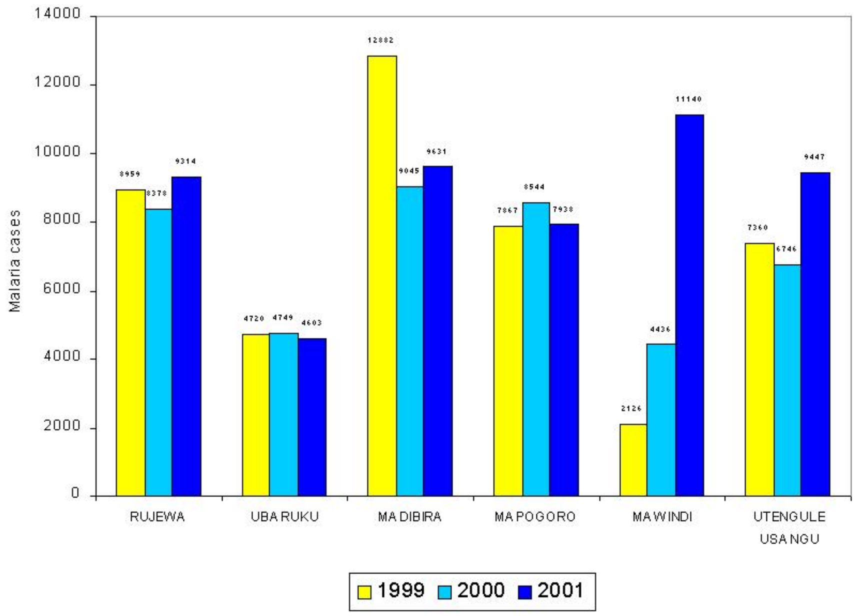


Figure 3. Yearly malaria variation in the wards of the study area

Figure 4 below indicates that malaria is proportional to the rainfall pattern and period of paddy activities. The maximum quarterly rainfall (300 mm) and maximum malaria incidences (1250) were recorded in 1999/2000 season for Rujewa ward. The absence of rainfall in July-September is well reflected by reduction in malaria incidence in the same year. In the 2000/2001 season the rainfall was higher and malaria cases responded similarly. Increased malaria incidences for July–September in 2000/2001 season compared to previous season may be due to stagnant water floods acting as best mosquito breeding environment.

The Malaria cases are high in the first quarter (Figure 4) followed by the second quarter. Similar findings were reported by (ISID 1994) that peaks for malaria cases are between October to February and December to April. In Usangu plains, usually these are periods for planting, weeding and high rainfall and the area is always characterized by increased amount of stagnant water and people working for long hours in the fields. During maturity and harvesting however, which is from June to August most of fields have less standing water and some are completely dry leading to fewer malaria cases in the third and fourth quarters (ISID, 1994). Also during the same period the standing water in irrigation canals and ponded surface water bodies close to homesteads are the only breeding environment for mosquitoes because most of households are less than a kilometre whereas mosquito vectors can fly up to a distance of 50 kilometres.

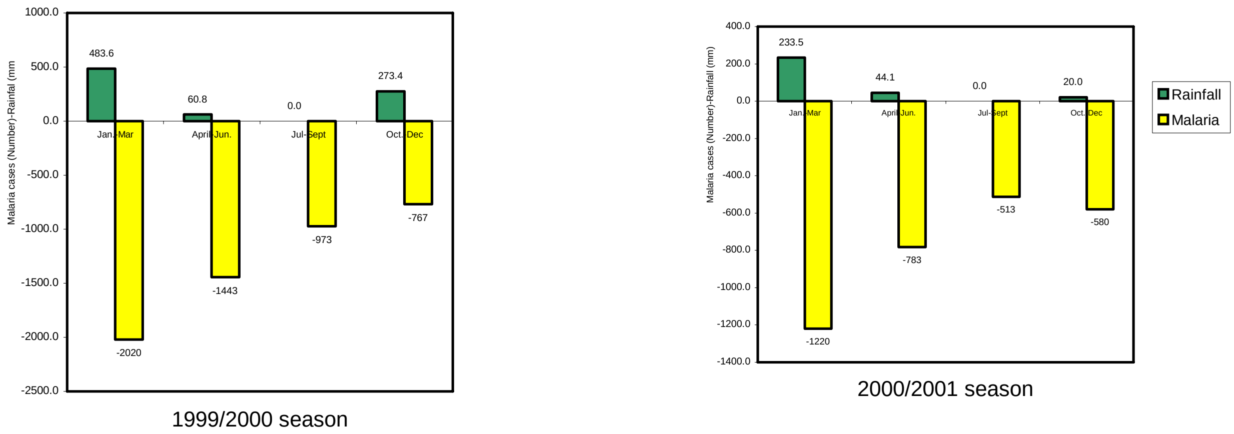


Figure 4: Relationship of Malaria with rainfall and irrigation in Rujewa

Water use and Management

Table 2 shows the average daily water levels maintained in paddy fields at different paddy activities in the study area. Rice activities starts early from September in modern and large irrigation schemes. The activities are relatively delayed in the improved and traditional smallholder farms as it depends on water availability from the large schemes and their main activities occur in the first quarter. The first and second quarter of paddy activities is when high water levels are maintained in paddy fields and at the same time field activities are at peak period. This is from transplanting to weeding stage of paddy. In the third quarter most of paddy has already been harvested but as observed many of the large irrigation fields do not dry completely by the end of quarter three. Unnecessary water abstraction especially during the dry season leads to more losses and continuous malaria vector cycles.

There is a difference of about 150 to 250 mm between recommended depths of up to 5omm and actual depths applied (Table 1) in large and smallholder irrigation schemes respectively. These depths are in excess of the requirement and may provide favourable environment for mosquito vectors. Though from farmers point of view they are of great importance such as in controlling weed and security against next unknown supply of water (Walker et al. 1987), the negative effects and the cost of reversing such practices are effectively unknown to many farmers. Halving these depths may enable a win-win situation whereby mosquito may be controlled and at the same time increasing the productivity of water.

Table 1. Average daily water levels in paddy field for 1999/2000 and 2000/2001 seasons

Irrigation system	Quarter	Average water levels (mm)		Activities
		1999/2000	2000/01	
Large and Modern	Jan.-Mar.	277	280	Puddling, Transplanting, Weeding
	Apr. -Jun	187	183	Harvesting
	July-Sept.	Moist	Moist	Field clearing, Tillage
	Oct.-Dec.	50	155	Tillage, Transplanting
Improved smallholder	Jan.-Mar.	175	175	Puddling, Transplanting, Weeding
	Apr. -Jun	165	115	Weeding, Harvesting, Bird scaring
	July-Sept.	Moist	0	Harvesting
	Oct.-Dec.	0	65	Nursery, Tillage
Traditional irrigators	Jan.-Mar.	177	173	Tillage, Puddling, Transplanting, Weeding
	Apr. -Jun	90	147	Weeding, Harvesting, Bird scaring
	July-Sept.	0	0	Harvesting
	Oct.-Dec.	0	0	Nursery, Tillage

The fact that high water depths decrease yield and productivity of water (<0.4kg/m^3 for individual fields in Usangu plains) cause of diseases is well documented (van de Hoek et al. 2001). Continuous flooding of rice resulted in increased water demand and health problems particularly malaria disease (van der Hoek et al., 2001).

Impact of Malaria to productivity

According to farmer's point of view in the study area, malaria is the most attacking disease. Their activities are therefore, limited by the number of days which member(s) of the family may suffer when attacked by malaria. Farmers from their experience ranked different activities in relation to likely losses that may happen if a member of the family is infected during particular cycle of paddy production. Using the pair wise ranking the activities were ranked as shown in Table 2. The ranks are based on how timely the operations for the first five ranks are important as far as productivity of paddy in concerned.

Table 2. Pair wise ranking on likeliness to lose yield when infected by Malaria

Activities		1	2	3	4	5	6	7	8	9	10	11	12	13	Rank
1	Land clearing	X													10th
2	Nursery	2	X												9th
3	Tillage	3	3	X											6th
4	Bunds making	4	4	3	X										7th
5	Puddling	5	5	5	5	X									3rd
6	Trash removal	6	6	3	6	5	X								7th
7	Seedling uprooting	7	7	3	7	5	7	X							6th
8	Transplanting	8	8	8	8	8	8	8	X						1th
9	Weeding	9	9	9	9	9	9	9	8	X					2nd
10	Bird scaring	10	10	10	10	5	10	10	8	9	X				5th
11	Preparation of harvesting ground	11	11	11	4	5	6	7	8	9	10	X			8th
12	Harvesting	12	12	12	12	5	12	12	8	9	12	12	X		4th
13	Transportation and storage	13	13	3	4	5	13	7	8	9	10	13	12	X	7rd
Frequency		0	1	6	4	10	4	6	12	11	8	3	9	4	

Malaria like any other water borne disease is normally high during the peak of activities in rice production like transplanting and weeding and therefore, significantly can reduce work outputs hence productivity of the entire household whenever one of members in infected (ISID, 1994). In Usangu plains a person diagnosed with malaria can take a period ranging 7-14 days to recover for full field activities (personal communication). This depends on early diagnosis, early treatment and good post malaria diet. The number of days may even be more if the above conditions are not met. The loss in productivity in terms of cost, number of days spent on bed by the patient and time spent by family members to attend the patient may even be higher.

The pair wise ranking results (Table 2) show that if malaria infection is acquired during transplanting, weeding, puddling, harvesting and bird scaring activity time frames will have a more impact on yield. The specific likely losses in were worked out by converting the individual ranks as a percentage of total ranks (Figure 5). The average percentage loss in productivity for any person infected by Malaria was estimated to be around 8%. Further it is estimated that serious malaria incidences may average to 3 occurrences per season for a household of 3 up to 7 members (personal communication). This may further suggest that the likely yield loss per household per year may be as high as 24%.

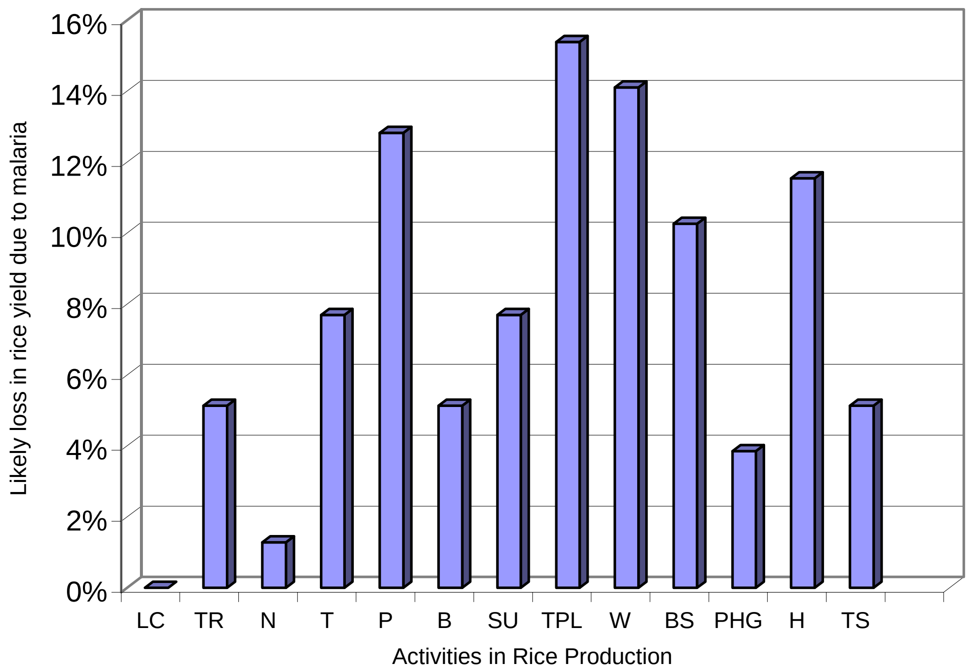


Figure 5: Percentage loss in rice productivity per activity[1]

Irrigation water management in Usangu plains as an environmental control can play a significant role in reducing the total number of malaria cases and at the same time improving the productivity of water in irrigated systems. Irrigation and management methods are such as alternate wetting and drying cycles and cleaning of irrigation canals for efficient water flows that discourage larvae breeding of malaria vectors. A cycle of 9 days wet and 2 days dry in 15ha field trials in Indonesia reduced the density of the malaria vector *An. Aconitus* by 75 percent. This research had a remarkable direct impact on decision-making and led the local administration to make alternate wetting and drying irrigation (AWDI) obligatory in Bali and Lombok despite some reduction in yield under AWDI (Konradsen et al., 1999). In trial plots in Kenya there was evidence that AWDI was effective against *An. funestus* and *An. coustani*, as populations of these species were much higher in the field under continuous irrigation, but not against *An.gambiae* and *An.pharoensis* (van de Hoek et al 2001). The advantage of wet and dry cycles irrigation is water saving from the practice, which can be allocated for other sector within or outside the irrigation systems. This is important in closing water basins, as in the

[1] LC = Land cleaning, N = Nursery, T = Tillage, B = Bunds making, P = Puddling, TR = Trash removal, SU = Seedling uprooting, TPL = Transplanting, W = Weeding, BS = Bird scaring, PHG = Preparation of harvesting ground, H = Harvesting, TS = Transportation and storage.

case of the Great Ruaha River of Usangu plains in dry seasons. Water saving of 17 percent of total available water was obtained by using AWDI compared to continuous flooding in Portugal (van de Hoek et al., 2001). The environmental control measures in irrigation systems like lining of canals might not be on balance profitable due to high costs compared to economical returns. But regular clearance of canals could benefit such systems because most of the canals and drains in the study area have weeds with standing water and are good breeding grounds of malaria vectors.

4. Conclusions and recommendations

There is a potential of reducing malaria incidences in the area through water management techniques. The correct window could be in quarter three when every farmer is harvesting. This could give a wider gap for occurrences of Malaria incidence in quarter four for the upstream and quarter one for the downstream users. Also alternate wetting and drying could be useful to reduce the number of breeding mosquito. This compares to the current continuous flooding of rice field at about 250 mm, which encourages high breeding rates.

The training of community based animators on prevention of Malaria specifically on the use of Insecticide Treated Nets (ITNs) under local initiative integrated malaria control (LIIMC) programme currently in practice in two out of existing eleven wards in Mbarali district would be very useful in controlling the disease. However marked poverty limits the success of this kind of approach and normally the number of malaria cases reported in health centres are just fraction of total malaria cases in the district.

Research to investigate malaria vector behaviour in irrigated fields and rice varieties under both continuous and intermittent supply of water is strongly recommended. The use of designated water management strategies to control malaria larval could be cheaper than the use of chemically based larvicides and might be widely adopted if there is no significant reduction in crop yield. Clearly such changes in water spreading and management have to be seen from farmers perspectives who often horde water as a perceived insurance against variability in supply and possible cessation or reduction of rains and river flow.

5. Acknowledgement

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