Discussion Paper

No. 02-3 **April 2002**

Malaria from the Gap: Need for Cross-sector Cooperation in Azerbaijan

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Abstract

This study examines the agricultural and institutional determinants of malaria in Azerbaijan during the period of 1998-2000 and suggests a control strategy to avoid future outbreaks. Regression method and geographical maps are used to identify significant policy variables for designing and implementing malaria control strategies. Lastly, a framework is introduced to identify the areas where and how agricultural research can contribute to the fight against malaria. The empirical analysis suggests that irrigation water use, soil salinity, and the current status (structural and institutional) of the former state-owned farms significantly contribute to the resurgence of malaria in Azerbaijan. Having identified these factors, the next step is to bring together the relevant government bodies and private organizations for a cross-sector cooperation. And guidelines and frameworks should be introduced to promote the development of rules and regulations that govern this cooperation.

Key words: Malaria, agricultural changes, knowledge gap, cross-sectoral cooperation, Azerbaijan

11 February 2003

1. **Introduction**[1]

Malaria, the world's most prevalent vector-borne disease, impoverishes more than 300 million lives throughout the world and kills at least one million each year. With the collapse of the former Soviet Union, the malaria situation started to worsen in some of its republics.[2] Azerbaijan is one such republic with a long history of dealing with malaria. Control measures were first introduced in the early 1930s, but in 1934 still there were a total of 600,000 reported malaria cases. By the 1960s, the disease was practically eradicated. In 1967 only 3 indigenous cases were recorded. However, malaria came back, with 22 cases of *Plasmodium vivax* in 1990. The number increased to 667 in 1994, to 2,840 in 1995, and jumped in 1996 to an alarming level of 13,135. Since then, the numbers are in decline, reaching a total of 1,530 cases in 2000 (WHO, 2001).

This decline does not mean the problem has been solved because conditions suitable for the transmission of malaria still prevail. The irrigation and drainage infrastructure needs rehabilitation, and water and environmental resources effective management. At the centre is land distribution that has, to date, induced substantial changes in agriculture. Large irrigation canals inherited from the old system are unsuitable to the current private farming system, creating mosquito-breeding habitats. Skills, knowledge, and income of private farm operators are inadequate to maintain soil fertility. New crop pattern, one away from fruits and vegetables exported to the former Soviet Union to cereals including rice and cotton[3], risks the effectiveness of anti-malaria measures due to farmers' lack of knowledge of appropriate irrigation techniques. Last but not least, about one million internally displaced people, mostly placed in the Southern districts where malaria has been epidemic after 1991, offer blood meals for mosquitoes.

These unfavourable conditions pose a more serious threat on the health status of current and future generations especially when one also considers the fact that Azerbaijan still lacks a long-term malaria control strategy and a monitoring and surveillance system for gathering data on the linkages between malaria and

[1] This study relates the findings of a joint ISNAR-WHO report, titled *Agricultural Development and its Impact on Malaria: Azerbaijan*, to the role of agricultural research in reducing the burden of malaria. In this respect, the author would like to thank Dr. Michail Ejov, Director of WHO-Roll Back Malaria Europe Program, for his support to the publication of the current study. The author would also like to thank Fuad Karimov and Vugar Ahmedov for their assistance in collecting data and officials in the ministries of agriculture and health for facilitating data collection. Thanks also go to Howard Elliott for his comments on and to Kayo Narita for her suggesting the title of the study.

[2] The term " malaria situation" is used very generally to denote one or more of the following: malaria vectors, mosquito breeding sites, malaria prevalence or incidence or resurgence, intensity of malaria infection, type of malaria parasites etc.

[3] For a broader range of reading on determinants of malaria, the reader is referred to Breman (2001), Packard (1986), Wang`ombe and Mwabu (1993), Fleming (1994), Hespanhol (1996), Konrades et al. (1998a, 1998b), Mutero et al. (2000); Nacher et al (2001), Mendis,et al (2001); Mouchet et al. (1998), Martens (1999), Martens et al. (1999); Martens and Hall (2000) among others.

agriculture. It further lacks an environment in which health, environment, and agricultural authorities can easily cooperate in the fight against malaria. Such cooperation might take place either in the planning and/or in the implementation stages; the cooperation is vital especially because the malaria situation strongly underlines poorly performing institutions, if they exist at all, reflected by ineffective management of water and land resources, poorly maintained irrigation and drainage infrastructure, and interrupted infrastructure rehabilitation activities.

Enhancing the depth of understanding -- possessed by decision makers in the ministries of agriculture, health, and environment, by experts in the agricultural research organizations and experiment stations, in public health clinics, and in environmental management offices, and by representatives of malaria-epidemic communities -- of the links between agricultural and environmental determinants and malaria should promote and support cross-sector cooperation. Therefore, with the current study, we explore how changes in agriculture introduced after 1991 have contributed to the resurgence of malaria and discuss how agricultural research can contribute to the fight against malaria. Specifically, we seek

- to identify the links between changes in agriculture and malaria,
- to advise on approaches for sustainable and cost-effective malaria control, and.
- to introduce a framework to indicate where and how agricultural research can play role in the fight against malaria.

Following the Introduction, Section 2 briefly presents the methodology applied and data used in this study. Section 3 discusses empirical results. Section 4 outlines a malaria-control strategy for Azerbaijan. Section 5 indicates the areas where and how agricultural research can play role in the fight against malaria. Section 6 concludes the study.

2. Methodology and Data

Two tools, regression analysis and geographical information systems (GIS), are applied to examine the association between the incidence of malaria and a set of agricultural, institutional, and geographical factors. The linear regression model below is separately estimated for the years 1998, 1999, and 2000 by using cross-section data for 1999 only:

$$M_i = b_0 + \sum_k b_k X_{ik} + e_i .$$

The estimations for 1998 and 2000 explicitly assume that the conditions in 1999 reflect, to a large extent, the conditions in 1998 and 2000. The term M_i stands for the incidence of malaria in district i *(1,…,58)*, defined as the ratio of the

number of malaria cases to the population. The *k*-th explanatory variable (*k=1,…,13)* in district *i* is denoted by X_{ik}. The set of explanatory variables used in the regression estimations can be divided into three groups. The first group comprises agriculture-related variables, including the number of formerly state-owned farms (Sfarms), the number of formerly collective farms (Cfarms), area of irrigated land (IrriHa), and area of agricultural land with severe salinity (SalinHa). The second group consists of institutional variables, including irrigation water used (IrriWa), water discharged (WaDisch), and the number of people per health facility (PopHos). The third group relates to geographical factors, including maximum temperature (Maxtem), average rainfall (AvRain), longitude (Lon), and latitude (Lat). The coefficient, b_k, denotes the marginal contribution of the *k*-th explanatory variable to the incidence of malaria. A statistically significant negative (positive) coefficient for the *k*-th variable would suggest that the incidence of malaria would decrease (increase) if the value of the *k*-th variable increases.

The second tool, a rudimentary form of GIS, is employed to overlay the spread of malaria and districts' selected agricultural (crops grown, arable land areas, etc), environmental (distribution of irrigation and drainage canals, swamps, water reservoirs, lakes, rivers, soil salinity, land erosion, etc), and climatic characteristics (temperature and precipitation). The overlays were then interpreted together with the regression results in order to identify visual patterns between malaria and the district characteristics and detect those districts for targeting malaria control activities.

Data used in this study were obtained from two sources: the Ministry of Health (MoH) and the Ministry of Agriculture (MoA). Data on the reported malaria cases were obtained from the MoH. And agriculture-related data from the MoA publications, including cropping patterns, spatial distribution of the former state/collective farms, maps showing the irrigation and drainage canals and swampy areas, the distribution of agricultural and irrigated lands, maps showing water reservoirs, lakes, and rivers, maps indicating temperature, precipitation, soil salinity, and soil erosion. Cross-section supplementary data were also collected for the year 1999, which is the only year for which data are available at the desired form (State Statistical Committee of Azerbaijan Republic, 2000). The district-level variables include the number of hospitals, the amount of water consumed for irrigation, and the amount of water discharged. Furthermore, the MoA sources were used to obtain data on the number of the former state and collective farms by district, population, average rainfall, maximum temperature, the amount of land subject to salinization and erosion, the amount of irrigated land, and longitude and latitude coordinates of districts.

3. Discussion of Empirical Results

3.1. Descriptive statistics

The 1999 correlation coefficients in Table 1 reveal two interesting associations. First, a large number of the formerly state-owned farms occupy irrigated lands, suggested by a correlation coefficient of 0.58. The same is not true for the formerly collective farms, as they were owned by and benefits were distributed among local communities. Second, considerable amounts of irrigated land were subject to soil salinity, implied by a correlation coefficient of 0.40. These two observations together imply that a typical state-owned farm suffers from soil salinity, which is expressed by a correlation coefficient of 0.30.[4] Other significant coefficients simply reflect the associations expected.

Table 2 reports annual correlations between present and historical malaria. The correlations suggest that malaria is cumulative. This observation is reflected by statistically significant positive correlations between malaria in 1993 and in the subsequent years, between malaria in 1994 and in the subsequent years, between malaria in 1995 and in the subsequent years, and so on. Cumulativeness implies that anti-malaria efforts should prioritize those communities with a long history of malaria, and that the prevalence of the disease should be used as a criterion for targeting public resources.

Table 3 gives descriptive statistics for 1999 of the explanatory variables. Interestingly, almost all of the variables (including Mal99, Hosp99, IrriWa99, WaDisch99, Pop, SalinHa99, and ErodHa99) have the kurtosis greater than 3 and the skewness greater than 5.6, suggesting that the variables are not normally distributed and their distributions are not symmetric.[5] In particular, for the distribution of malaria, the kurtosis of 37 implies that malaria has been widespread in few districts and relatively limited in others. Similar interpretations should also apply to the irrigation water use, water discharge, soil salinity, and land erosion.

3.2. Regression estimations

Separate regression models were estimated for 1998, 1999, and 2000, under the assumption that the conditions in 1999 prevailed in 1998 and 2000 also. This is not an unreasonable assumption because irrigation water use, land quality, climate, population, and public service facilities are not likely to change dramatically within a year. What is striking in these estimations is the robustness of the two variables: irrigation water consumption and soil salinity (Table 4). This finding strongly suggests that the improved management of irrigation schemes and soil fertility would reduce the incidence of malaria. The improved management capacity should not only accelerate the applications of more effective irrigation schemes but also empower local water authorities with

[4] The term "99" attached to the variable concerned indicates the year it belongs to. Of these correlation coefficients, those above 0.30 are considered significant.

[5] In statistical theory, normally distributed variables are expected to have a kurtosis of 3 or less. The kurtosis is a measure of the peakedness (if positive) (or the flatness if negative) of and the thickness of the tails of a distribution. The skewness of a distribution refers to its degree of symmetry.

knowledge and skills necessary to facilitate community level collective activities. The need for the improved management becomes clear when one considers that, as of 1996, over 80 percent of the irrigation schemes were still larger than 20,000 ha, and that many of them were state owned. And, only 1% of the irrigated land was under private irrigation schemes, and not much has changed since then (FAO, 1997).

Needless to say, the negative effect on malaria of irrigation water consumption is directly related to the current poor status of many irrigation canals and drains, along which mosquito breeding habitats are mostly seen. Almost 90 percent of the irrigation was surface irrigation, mainly from reservoirs and through direct pumping in rivers and canals. Unorganized irrigation practices, intensive plane wash out at slopes, and widespread marshes in the South created optimal breeding habitats in low lands. Furthermore, the drainage network covering almost 600,000 ha land is mostly situated in irrigated land, and 350,000 ha of drained land need major rehabilitation.[6]

Although mosquito-breeding habitats could be reduced in number by cleaning canals in the areas where soil had drainage problems, this had not been done due mainly to the absence of local organizations to initiate collective cleaning activities. The South districts, where agriculture without irrigation is not viable, have a suitable climate for mosquito breeding, with the average temperature of 25-26 C, the maximum temperature of 42 C in summers, and the average rainfall around 300 mm per year. Imishli, for example, is irrigated from two large canals, Upper Garabag and Bas Mil Garabag Collector, both originating from the Kura river at Mingechevir. These two irrigation canals appeared to be in a better state of maintenance than did drains.

Soil salinity is more of a symptom rather than a cause of malaria. Water is needed to flash out the salt from the soil, but this will only be effective with upgraded drains. Of the 1.45 million ha irrigated land, 615 000 ha are subject to various degrees of salinity. The most detrimental salinity occurs in the Kura-Araks lowland.

3.3. Spatial distribution of malaria and environmental/agricultural factors

Adverse environmental conditions around poorly maintained irrigation and drainage canals have created mosquito-breeding habitats. Marshes, water pools, wetlands, and small swamps occupy a large area around the Kura river and the Mugano-Salyan canal due to the infiltration of irrigation water, high ground water tables, interrupted road constructions, seepage water from adjacent earthen canals, and poorly maintained drains. As seen from Figure 1, such conditions prevail especially in Imishli, Sabirabad, Bilasuvar, Saatli, Ujar, and Aghjabadi (Margalith, Boelee, Zohar, and Kaiser, 2000). A significant amount of arable land in the Kura-Araks lowland is also subject to medium-to-severe

[6] See FAO (1997) for a detailed description of areas where rehabilitation is required.

salinity (Figure 2), which requires upgraded irrigation and drainage infrastructure in the Upper Garabagh, the Upper Shirvan, and the Mugano-Salyan channels.

These adverse conditions appear to be more detrimental especially in districts where the formerly state-owned farms are located (Figure 3). This is also suggested by the 1998 regression estimation given in Table 4, where the variable Sfarms has a positive and significant effect on the incidence of malaria. Given the significance of the geographic distribution of these farms, all of which are currently in private hands, the still presence of large farms demands new institutional set up to deal with irrigation water use problems.

In near future, a cereal-cotton production pattern, which is the dominant pattern in the malaria epidemic districts in the South (Imishli, Beylagan, Bilasuvar, Sabirabad, and Saatly), is also likely to emerge in the Shirvan region having lots of marshes in the Ujar, Kurdamir, and Zerdab, and Hajigabul districts (Figures 1 and 4). Therefore, remedies should be taken now to avoid future epidemics, including a plan for the management of water tables, irrigation and drainage infrastructure, irrigation water use and land use.

The malaria situation has been worse in the Southern districts, and two main reasons lie behind it. One, these districts lack local water management bodies, although agriculture is mainly irrigated (Figure 5). Irrigation water distribution from large to poorly maintained small canals create optimal mosquito breeding places. Another, only in 1998 have institutional arrangements been made to organize drinking water, sanitation, and malaria control. Presently, the supply of drinking water is under the responsibility of the Ministry of Community Affairs, and sanitation and malaria control are under the Ministry of Health.

Characteristics of mosquitoes in Azerbaijan

Five mosquito specimens, A. sacharovi, A. malculipennis, A. subalpinus, A. superpictus, and A. hyrcanus, were found to transmit malaria in the Imishli, Saatli, and Sabirabad districts in South. Of these specimens, A. sacharovi, the major carrier of malaria; prefers water with a high content of oxygen (12.4mg/liter on average) and occurs rarely in water environments containing high concentrations of phosphates nitrities, chlorides and nitrogen. This mosquito is able to tolerate moderately salty water (up to 4-4.5 mg/liter), which explains its abundant breeding in Imishli, Saatli, and Sabirabad (Figure 2). It also prefers habitats with temperatures varying between 19 C and 34 C, breeds in lakes, swamps, irrigation canals and drainage ditches, pools, and similar water bodies with slowly flowing water. A. subalpinus, A. superpictus, A. maculipennis, and A. hyrcanus are among secondary vectors of malaria transmission. A. superpictus breeds mainly in cool highlands. Larvae of A. hyrcanus are found more frequently than those of A. superpictus, especially in the moderately salty waters. However, since A. hyrcanus can exist only in limited habitats, its capacity to spread malaria is low (Margalith, Boelee, Zohar, and Kaiser, 2000).

4. An Approach to Controlling Malaria in Azerbaijan

The analysis in the current study underlines two observations. Firstly, the adverse environmental conditions still prevail in malaria-epidemic districts, including small water bodies, high water tables, poor drainage facilities, and poor road infrastructure (Margalith, Boelee, Zohar, and Kaiser, 2000). Unless community level activities are initiated, these adverse conditions are more than enough to bring about an outbreak. The situation is especially threatening in Imishli, Bilasuvar, Sabirabad, Saatli, Beylagan, and Fuzuli districts in South and Baku on the Caspian Sea, and that Aghjabadi, Zerdab, Kurdamir, Hajigabul, Alibayramli, Salyan, and Absheron districts (Figure 3). Secondly, anti-malaria efforts should consider the effects on malaria of institutional factors, including irrigation water use, land quality, and the infrastructural conditions in which new large farms operate. These efforts should be initiated at the community-level, as the conditions suitable for malaria are often community-specific, and should target those communities with a high level of malaria prevalence.

In view of these observations, anti-malaria measures would be more effective if mosquitoes were attacked on multiple fronts in a coordinated manner. The management of agricultural and environmental determinants should be the first front in the fight against malaria. This is a long-term approach that requires institutional changes to deal with the deteriorating agricultural and environmental conditions. On the agricultural side, the key factor behind the disease seems to be ineffective water use for irrigation and weak management of administrative bodies responsible for the allocation of irrigation water.

A second front should embrace biological and chemical vector control strategies to reduce the abundance of vectors by biological agents like natural predators and microbial insecticides and by chemical use like residual insecticides. As discussed by Margalith, Boelee, Zohar, and Kaiser (2000), actions in this frontier are being implemented in the southern district of Azerbaijan. The residual insecticides are sprayed indoors, and surface water is stocked with Gambusia fish, which have been found very effective bio-control agents. Although *Eucalyptus camaldulensis* seems to be the most suitable species compatible with the environmental conditions in the region, and potential exists for propagation of *Eucalypts*, local knowledge is inadequate for growing *Eucalyptus* trees. In Imishli, for example, no Eucalyptus trees are grown, although soil type and salinity appear very suitable for plantations of E. camaldulensis.

But, fighting against malaria on several fronts without coordination among them would be both ineffective and cost-inefficient because, in the absence of a concerted and coordinated cross-sectoral fight, many measures initially thought to be effective are likely to result in negative side effects in other sectors. In Azerbaijan, ample scope exists for cross-sectoral coordination of activities because sources of malaria are diverse and side effects are at large scales, but at the moment institutional innovations are not in place for a cross-sectoral framework to be developed and for the institutional constraints to be released. The task now

is to identify critical gaps in understanding of where joined forces from the agricultural, environmental, and health sectors will make a difference in communities at risk.

Such an inter-sectoral framework should help prevent future threats leading to the spread of malaria. First, rising water levels in the Caspian Sea have reversed the decades-long drying trend and now threaten coastal areas. It requires relocation of several settlements to be planned and measures to be taken to protect those settlements that will be brought in close proximity with water.

A second threat is changing crop patterns. With the heaviest precipitation and varying climates, the Lenkoran lowland is suitable for rice cultivation. With improved farm income, farm households soon will be able to get out of the subsistence farm production and add rice farming to their operations. As is already documented by Margalith, Boelee, Zohar, and Kaiser (2000), rice cultivation would prepare suitable conditions in the Lenkoran lowland for *A. sacharovi, A. malculipennis, and A. hyrcanus*. Remedies should be taken now before it becomes late, including training farmers about rice irrigation techniques.

Third, parasites in already infected population wait to be activated, and therefore those infected in malaria-epidemic communities must be targeted for control and medically treated before applying the spraying of insecticides to the community without discrimination. This way, both cost will decline and measures will be more effective. To successfully implement this strategy, the targeted malaria control approach should be adopted, as patients who had malaria in previous years often relapse (Eberlee, 2001). Treating a community would not be enough to avoid the resurgence of malaria because the parasites are dormant in the livers of the patients, and when the mosquitoes come back, the parasites revive and malaria returns. An effective strategy should target those who had malaria in the year or two before the current transmission season to stop them from having a malaria episode and then spray their homes. In this way, the cycle of transmission can be blocked. It is important that not everyone is treated because the malaria parasite will become increasingly drug resistant.

It should not come as a surprise that cross-sectoral collaboration is indispensable to cope with the expected negative side effects of the rising water level in the Caspian Sea, changing cropping patterns, and sleeping parasites. Relevant authorities to cooperate include the Ministry of Agriculture for the issue of changing crop pattern, the Ministry of Health for the issue of controlling dormant parasites, the Ministry of Water Management for the issue of rising water level, and the Ministry of Community Affairs for the rehabilitation of rural infrastructure.

5. Rational for Agricultural Research

5.1. Agricultural determinants of malaria

Agricultural determinants of malaria in Azerbaijan can be classified in three sets.[7] The first relates to the shift from centrally planned to market oriented farming system, which is characterized mainly by land reform and privatization of the formerly state-owned farm assets. Agricultural land and farm equipment have been distributed among the rural population, but the irrigation and drainage system has not thus far been adjusted to the needs of new farms due mainly to inadequate finance and absence of institutions. Slow progress in the development of formal rules, regulations, and procedures that govern land transactions, irrigation water use, and credit markets has pushed new private farmers into subsistence-oriented farming. Adverse environmental conditions including poorly maintained irrigation and drainage canals, combined with low farm production and hence income, have created favourable conditions for the transmission of malaria (WHO, 2001).

The second set concerns the lack of new agricultural practices. For example, there is a need for the development of new irrigation methods for farming in areas where soil presents drainage problems and in areas where cotton or rice is more likely to be cultivated in near future. It is, therefore, desirable to develop new cotton or rice varieties suitable for dry areas so as to reduce farmers' contact with water. With significant amount of cotton fields surrounded by marshes, the South districts of Azerbaijan, for example, appear to be potential areas for the resurgence of malaria.

The third set relates to poor management of agricultural resources, including water and land. Rising ground water tables create perfect mosquito breeding habitats in the idle lands of the South districts. And a great deal of agricultural land situated in the Kura-Araks lowland suffers from loss of soil nutrients. Investment in land is necessary to regain these once-fertile lands, but this requires the completion of ongoing legal arrangements to ensure new farmers' land use and ownership rights. Such legal security should considerably change new farmers' attitudes toward the fight against malaria. One such change will be community-level collective activities to fill small puddles around irrigation and drainage canals, which are the critical sources of mosquito breeding. Such activities will be critically important due especially to daunting public services.

5.2. Role of agricultural research in the development of institutions

In Azerbaijan, decision makers both at the macro and micro levels all recognize environmental determinants of malaria, but the very same decision makers disregard its agricultural determinants discussed above due mainly to poor understanding of the links between changes in agriculture introduced after 1991 and the resurgence of malaria that followed. As a result, little effort is made to establish institutions (defined as formal rules, regulations, and procedures) for identifying and monitoring changes in human health in relation to changes in

[7] See Bradley (1994) for a thorough discussion of the bi-directional linkages between agriculture and health.

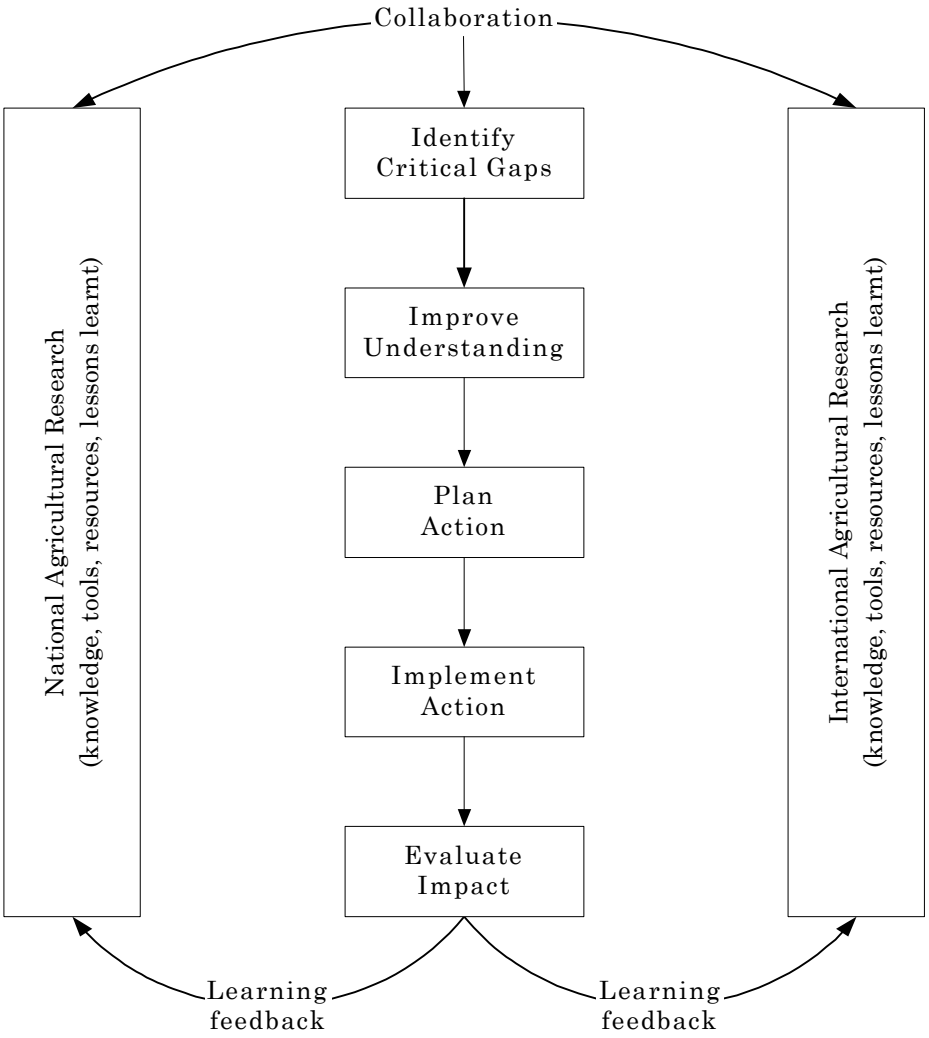
agricultural and environmental determinants and for promoting cross-sector cooperation among the government bodies responsible for the health, environment, agriculture, and community affairs in the planning and/or implementation of agricultural development projects.

The development of institutions concerned should start with commitment at the policy level to secure resources for establishing new or improved government bodies with necessary human and physical resources. Under normal conditions, such commitment would strongly depend on the knowledge available and/or to be generated on the links between agriculture and malaria. Therefore, agricultural, health, and environmental research all have a role to play in promoting this commitment. Once established, the commitment should be transformed into action by designing formal rules and regulations to coordinate the activities of the government units concerned and to facilitate the interaction between relevant public and private bodies. Creating inter-ministerial committees, multidisciplinary networks of experts, partnerships between public and private bodies, etc. are among the ways to accomplish this. Needless to say, the very same research should also provide input to the committees, networks, and partnerships formed.

What specific roles should agricultural research play in the process of institutional development? There are at least five roles for agricultural research, which are:

- to identify critical gaps in understanding of the links between agriculture and malaria,
- to improve understanding of these links by generating, distributing, and applying useful knowledge,
- to help plan action to avoid adverse health effects of agricultural activities,
- to help implement action in cooperation with communities or relevant organizations, and
- to evaluate its impact on wellbeing of population concerned and draw lessons for future (Figure 6).

Figure 6. A Framework for Capacity Development



All these roles can be performed successfully only if national research and other organizations have capacity to do so. Therefore, international agricultural research organizations should first help develop capacity of the national organizations in organizational (i.e., managerial, human, and physical) and institutional terms.[8] For example, identifying critical gaps and improving the understanding of them require capacity to collect and analyze data and then to generate knowledge of the workings of complex processes. Improving the understanding further requires capacity to apply the generated knowledge to different situations, to derive lessons from the applications, and to accumulate

[8] Following Paul (1994), we use the term "capacity development" to refer to the creation, expansion, and upgrading of a stock of desirable qualities and features that could be continually drawn upon over time. Capacity development is thought in terms of knowledge, processes, and practice. Knowledge focuses on the analytical and substantive understanding and skills to be built up. Processes refer to the institutional strengths and dimensions to be created. Practice is the means by which both knowledge and processes are internalized and reinforced.

the lessons. Planning and implementing actions require skills for networking, consultation, negotiation, conflict management, etc. Evaluating the impact of the research and deriving lessons call for individual capacity to apply impact assessment tools and organizational capacity to accumulate and internalize the knowledge. Finally, a distinct capacity should be developed at the managerial level to regulate and monitor the process in which individual roles are performed. Once developed, these capacities would place agricultural research organizations in a position to respond effectively to changes in human health resulting from agricultural activities.

In view of the fact that the agriculture-health system comprises the agriculture, environment, and health sectors, enhancing the capacity of agricultural research only is not enough for this system to be effective. The environment and health research should also be in the position to respond to changes in human health. Unless and until they all have the capacity to monitor changes in human health and share information with each other, the research feedback will be poor from changing health status of population concerned to the agriculture-environment-health research nexus. And this poor feedback will further jeopardize the effectiveness of the agricultural research to help avoid agricultural activities with adverse health effects.

5.3. The systems approach to capacity development

The systems approach is an appropriate tool both to identify weak linkages in the agriculture-health system and to suggest capacities required to strengthen them.[9] For example, if weak interaction exists between the agricultural research and farm organizations, developing participatory research capacity can be considered one of the strategies to follow. If, on the other hand, weak linkage exists between agricultural research and health information unit in the ministry of health, then formal rules and regulations will be desirable to establish a permanent exchange of information between them. It should not come as a surprise that the levels of capacity development activities also vary depending on the agents or organizations interacting. In the first example, capacity should be developed at the community level, while in the second example capacity be developed at the sectoral policy level.

Learning is central to the systems approach based on interactions of a set of agents organized around a common goal. Therefore, these agents are expected to learn from each other towards this goal. It is this learning that should facilitate the transfer of capabilities already developed by an organization to others in the system. To promote this learning process further, organizational forms such as networks, partnerships, and committees should be initiated, and institutions providing a framework for organizational interactions introduced.

[9] See Goldsworthy and de Vries (1994) for a wide range of applications of the systems approach in agricultural development issues of developing countries.

6. Concluding Remarks

This study examined the agricultural and institutional determinants of malaria in Azerbaijan during the period of 1998-2000 and suggested a control strategy to avoid future outbreaks. Regression method and geographical maps were used to identify important policy variables for designing and implementing malaria control strategies. Lastly, a framework was introduced to identify the areas where and how agricultural research can contribute to the fight against malaria. The empirical analysis suggests that irrigation water use, soil salinity, and the current status (structural and institutional) of the former state-owned farms have significantly contributed to the resurgence of malaria. Especially important is the evidence that weak institutional development regarding irrigation water use, maintenance of soil fertility, environmental protection, and community infrastructure have been among the main causes of malaria in Azerbaijan.

Having identified the linkages between agriculture and the resurgence of malaria in Azerbaijan, the next step is to bring together the relevant government bodies and private organizations for a cross-sector cooperation. And guidelines and frameworks should be introduced to promote the development of rules and regulations that govern this cooperation. Only then will decision makers at the policy, firm, farm, household levels consider possible health effects of their actions.

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Table 1. Correlation coefficients, 1999

	Mal99	IrriWa99	IrrigHa99	Sfarms	Cfarms	SalinHa99	ErodHa99	WaDisch99
Mal99	1.00							
IrriWa99	0.17	1.00						
IrrigHa99	0.07	**0.71**	1.00					
Sfarms	0.04	**0.58**	**0.51**	1.00				
Cfarms	-0.16	-0.14		**-0.32**	1.00			
SalinHa99	0.07	0.20	**0.40**	**0.30**	-0.09	1.00		
ErodHa99	-0.04	0.01		-0.08	-0.07	-0.03	1.00	
WaDisch99	0.16	-0.02		-0.15	-0.13	-0.02	-0.03	1.00
AvRain99	-0.16	**-0.39**	**-0.37**	-0.16	0.02	-0.22	-0.17	-0.14
Maxtem99	0.18	**0.45**	**0.29**	0.18	0.01	0.26	0.16	0.20
Lat	0.20	0.13		0.01	-0.24	0.13	0.14	0.23
Lon	-0.07	0.22	0.04	0.16	-0.14	-0.05	-0.08	-0.12
Pop	**0.91**	-0.06	**-0.10**	-0.14	-0.08	-0.07	-0.04	0.14
Hosp99	**0.86**	0.03	0.00	-0.11	0.03	-0.03	-0.08	0.11

Table 1. Correlation coefficients, 1999

	AvRain99	Maxtem99	Lat	Lon	Pop	Hosp99
Mal99						
IrriWa99						
IrrigHa99						
Sfarms						
Cfarms						
SalinHa99						
ErodHa99						
WaDisch99						
AvRain99	1.00					
Maxtem99	**-0.40**	1.00				
Lat	**-0.38**	0.19	1.00			
Lon	0.00	-0.03	0.01	1.00		
Pop	-0.08	0.06	0.18	-0.04	1.00	
Hosp99	-0.07	0.13	0.05	-0.10	**0.95**	1.00

Table 2. Cross-section correlation coefficients

	Mal91	**Mal92**	**Mal93**	**Mal94**	**Mal95**	**Mal96**	**Mal97**	**Mal98**	**Mal99**	**Mal00**
Mal91	1.00									
Mal92	**1.00**	1.00								
Mal93	0.17	0.13	1.00							
Mal94	0.00	-0.03	**0.57**	1.00						
Mal95	**0.36**	**0.34**	**0.46**	**0.46**	1.00					
Mal96	**0.63**	**0.59**	**0.48**	**0.39**	**0.72**	1.00				
Mal97	0.24	0.21	**0.52**	**0.45**	**0.61**	**0.88**	1.00			
Mal98	0.21	0.17	**0.75**	**0.54**	**0.58**	**0.79**	**0.91**	1.00		
Mal99	0.05	0.04	**0.82**	**0.36**	**0.49**	**0.33**	**0.44**	**0.67**	1.00	
Mal00	0.02	0.01	**0.80**	**0.29**	**0.41**	0.22	**0.33**	**0.55**	**0.97**	1.00

Table 3. Descriptive statistics, 1999

	Mal99	Hosp99	IrriWa99	WaDisch99	Sfarms	Cfarms	Pop
Mean	36.7	10.8	56.1	69.8	14.7	8.7	124.7
Median	13.0	9.0	24.0	0.0	8.0	6.0	83.0
Mode	0.0	7.0	0.0	0.0	0.0	1.0	84.0
Standard Deviation	80.9	12.4	78.5	331.0	15.0	8.8	230.2
Kurtosis	37.4	38.0	4.5	37.9	1.2	1.1	51.0
Skewness	5.7	5.6	2.1	6.0	1.2	1.3	7.0

	AvRain99	Maxtem99	SalinHa99	IrrigHa99	ErodHa99	Lat	Lon
Mean	478.4	31.7	12403.9	22841.5	690.3	47.4	40.4
Median	389.5	32.6	6415.0	20603.5	41.4	47.4	40.3
Mode	300.0	34.4	0.0	0.0	0.0	49.0	40.4
Standard Deviation	257.2	4.0	26613.1	18942.7	4851.0	1.6	1.4
Kurtosis	0.5	-0.6	39.9	-1.2	58.0	7.2	9.3
Skewness	1.0	-0.8	5.9	0.4	7.6	-1.8	2.4

Table 4. Regression estimations

	Dependent variable: incidence of malaria								
Independent		**1998**			**1999**			**2000**	
Variables	*Coefficients*	*t Stat*	*P-value*	*Coefficients*	*t Stat*	*P-value*	*Coefficients*	*t Stat*	*P-value*
Intercept	0.0090657	1.29	0.20	0.00278243	1.58	0.12	2.227E-05	0.02	0.98
Irrigation water consumption 99	**0.0000072**	**2.25**	**0.03**	**0.00000217**	**2.72**	**0.01**	**1.023E-06**	**2.50**	**0.02**
Irrigated land (Ha) 99	0.0000000	-1.15	0.26	0.00000000	-0.51	0.61	-5.723E-11	-0.04	0.97
Number of state farms 99	**0.0000302**	**2.26**	**0.03**	0.00000189	0.57	0.57	6.973E-08	0.04	0.97
Number of collective farms 99	0.0000162	0.87	0.39	-0.00000032	-0.07	0.95	-2.797E-06	-1.17	0.25
Agr. land suffering salinity (Ha) 99	**0.0000000**	**2.23**	**0.03**	**0.00000000**	**2.17**	**0.04**	**1.440E-09**	**1.80**	**0.08**
Agr. land suffering erosion (Ha) 99	0.0000000	0.01	0.99	0.00000000	-0.14	0.89	-3.580E-09	-0.91	0.37
Water discharged 99	-0.0000002	-0.42	0.68	0.00000001	0.11	0.91	-2.401E-08	-0.40	0.69
Average rain 99	-0.0000002	-0.28	0.78	0.00000005	0.28	0.78	1.003E-07	1.15	0.26
Maximum temperature 99	0.0000159	0.35	0.73	0.00001693	1.49	0.14	**1.461E-05**	**2.50**	**0.02**
Latitude	-0.0000695	-0.67	0.51	-0.00002849	-1.10	0.28	-7.884E-06	-0.59	0.56
Longitude	-0.0001641	-1.41	0.17	-0.00004706	-1.62	0.11	-3.361E-07	-0.02	0.98
Population per hospital or clinic 99	0.0000000	1.15	0.25	0.00000000	0.69	0.50	-1.099E-09	-0.50	0.62
Multiple R square	0.67			0.69			0.73		
Observations	58			58			58		