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A GIS SUPPORTED RISK-ANALYSIS OF THE RETURN OF MALARIA IN NOORD-HOLLAND

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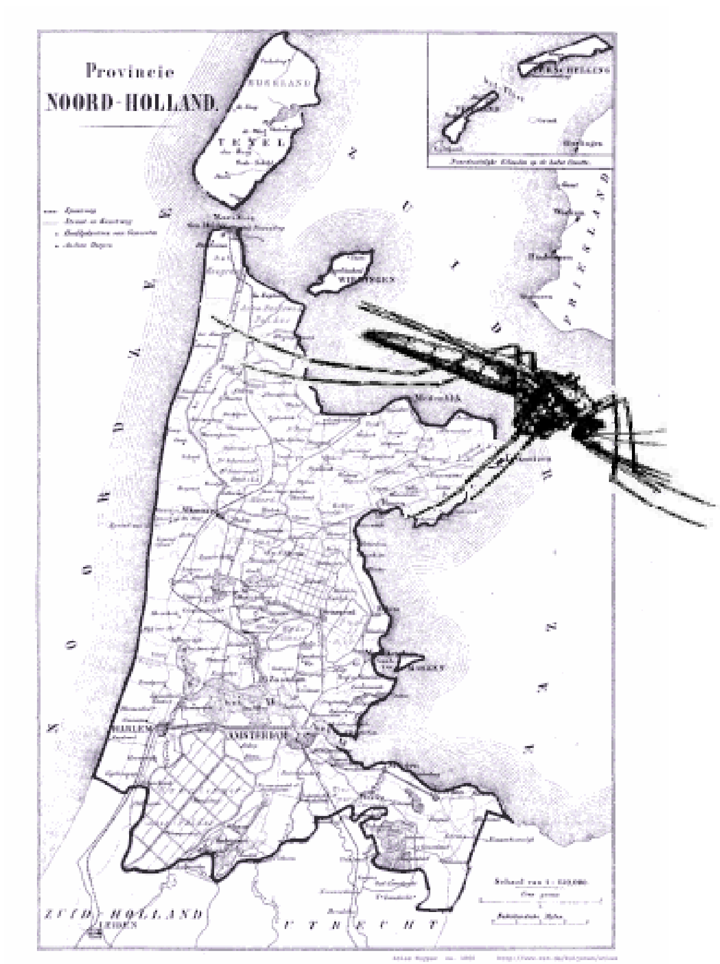

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A GIS SUPPORTED RISK-ANALYSIS OF THE RETURN OF MALARIA IN NOORD-HOLLAND

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Preface

To complete the Master study Geo-Information Science a thesis research has to be done. The Radboud hospital in Nijmegen, which is doing research to the disease malaria, provided a thesis topic. This topic was predicting the malaria risk in the Netherlands under different circumstances with a simulation model.

The research was done under the supervision of three supervisors; Jan Peter Verhave a malaria (disease) expert of the Radboud hospital in Nijmegen, Willem Takken malaria (mosquito) expert of the Wageningen University and research centre and Ron van Lammeren GIS expert of the Wageningen University.

I have experienced that a thesis is a valuable part of your education, doing this thesis I learned how to do a research on my own. In the beginning some problems caused delay since it was hard to concentrate on the thesis. This in combination with the fact that starting the thesis was difficult task for me. After a slow start the thesis went well and I have learned a lot from it. Therefore I would like to thank my supervisors for their patience and faith in me.

I want to thank Willem Takken en Jan Peter Verhave for all the expert information they gave me about malaria and for their help in completing the thesis. I want to thank especially Ron van Lammeren for all the time he spent on the thesis and supervising the thesis and the thesis process.

Margriet Liemburg

Abstract

Till approximately 1960 malaria occurred endemic and sometimes epidemic in the Netherlands, since than no native malaria cases occurred in the Netherlands. Nowadays the environmental conditions for malaria mosquitoes are improving and assumed is that mosquito densities are increasing, now the question rises; “will malaria return in the Netherlands”. In the Netherlands the disease malaria is caused by a plasmodium, named *Plasmodium vivax*. The disease is transmitted by female malaria mosquitoes of the *Anopheles* genus. A malaria mosquito becomes carrier of the plasmodium when biting a infected organism. A parasite carrying mosquito is able to transmit it to other organisms. In history the mosquito *Anopheles atroparvus* was the vector of malaria in the Netherlands, *Anopheles messeae* is a strongly related mosquito which is a potential malaria vector. Both mentioned species of Anopheles mosquitoes still exist in the Netherlands, but the native form of *Plasmodium vivax* for the Netherlands doesn’t exist anymore. However in other countries other forms of *Plasmodium vivax* exist which in theory can be transmitted by *An. atroparvus* and *An. messeae*.

In order to predict the malaria risk in the Netherlands a thesis research has been done. A simulation model supported by GIS was made in order to predict the malaria risk in the future. The research was focused on the Dutch province Noord-Holland, this province was one of the areas where malaria epidemics appeared in history and the major focus for malaria research.

The simulation model consists of twelve input parameters (state variables) which have big influence on the existence of malaria mosquitoes and the disease malaria. These state variables are divided into three main data groups; *climatic data*, *habitat data* and *demographic data*. Data for the state variables is gathered for the years 1934, 1992 and 2003. The state variables have been used to calculate the *vectorial capacity*. This vectorial capacity represents the number of malaria cases if *Plasmodium vivax* is present. The model calculates the number of malaria cases per municipality per month and the results are displayed in the form of maps and database tables. The simulation model is built with help of the GIS programs: ArisFlow and ArcInfo. ArisFlow Commander is used to run the model. The model is built in a user friendly way to make it accessible for different types of users.

Calibration of the model is done by using data for the year 1934. In this year malaria occurred in Noord-Holland and data about the number of malaria cases per district are available. Results of the calculations done by the model are compared with the actual number of malaria cases in the year 1934. The model functions well but unfortunately no perfect match during calibration has been found yet. This is most probably caused by the fact that not all data was detailed enough and the fact that not all data was available in the right format. Due to inaccuracies in estimations and data processing the model calibration was not completely successful. To calibrate the model the *feeding frequency* and the *daily mosquito survival rate* were adjusted. A *daily biting rate* of **0,30** and a *daily mosquito survival rate* of **0,79** gave the best match.
When using the settings of the “best match” from the calibration, the model gives the output that malaria can exist in the year 2003 at a density of 300 mosquito larvae per m^2. It has to be noticed that the model calculates the number of malaria cases, assuming Plasmodium *vivax* is present. In reality the plasmodium is only present when a carrier of imported malaria gets bitten. This chance is relatively low because of the good medical care in the Netherlands, but one can carry malaria without knowing it.

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1 Introduction

1.1 Context and background

A lot of people know malaria as a tropical disease not appearing in Europe, nothing less is true. Only from the year 1970 the Netherlands are officially declared malaria free by the World Health Organization. Other European countries like the former USSR and Turkey are still suffering from malaria as can be read from figure 1.1; *Autochthonous malaria cases in Europe* of the WHO.

Imported malaria from other countries is nowadays becoming more and more a health issue. Many people travel from one country to another for businesses and holidays and the chance that some of these people bring malaria along is not neglectable. Also fugitives from foreign countries requesting asylum are potential malaria carriers. Since the early 1970s the reported number of imported cases in Europe increased ten-fold, from 1500 cases in 1972 to more than 15000 in the year 2000 *(WHO, website).*

Malaria is an infectious disease, which is caused by plasmodia, transmitted by female mosquitoes of the *Anopheles* genus. When a person gets bitten, the plasmodium enters the body by the saliva of the mosquito. Malaria causes severe fever attacks and may even cause dead.

The densities of mosquitoes in the Netherlands, which may carry and transmit malaria parasites, is assumed to be rising because of improved environmental conditions. Because of these improved living conditions for the “malaria'' mosquitoes, the question arises; “will malaria return in the Netherlands?”. To answer this question a risk analysis, about the chance of return of malaria in the Netherlands, should be made. In order to simulate the change on return of malaria in the Dutch province Noord-Holland a GIS based simulation model (for malaria risk) was made.
The simulation model was built by using GIS. GIS is an excellent tool for making such a simulation model; it is for instance used to visualize complex problems. For the research *ArcView* and *ArcInfo* have been used. With these programs the malaria risk can be calculated and displayed spatially. The simulation model and the results are explained in this report. By means of state variables, determining the conditions for malaria mosquitoes and the plasmodium, the malaria risk can be calculated. Since the state variables can be adjusted to different locations the model can possibly be used for different locations in the Netherlands.

In chapter 2, *Malaria mechanism*, the disease malaria and its vectors (malaria mosquitoes) are discussed. Chapter 3, *Conceptual model*, explains the simulation model in detail. A schematic representation of the simulation model is shown and all model parts are handled in this chapter. Chapter 4, *Case study Noord-Holland*, describes the research area and the gathering, processing and relevance of the data used in the simulation model. The construction of the model and the working of the model is explained in chapter 5, *The Application.* In chapter 6, *Results*, the results of the model calculations are displayed. The conclusions and recommendations are described in chapter 6; *Conclusions and recommendations.*

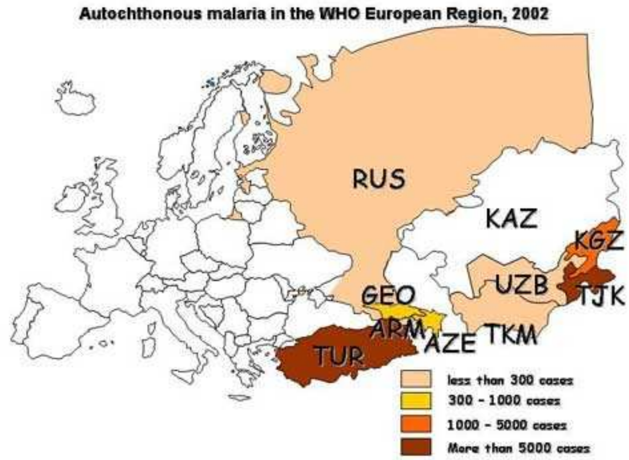


Figure 1.1: Autochthonous malaria cases in Europe (website WHO).

1.2 The research

1.2.1 Introduction

The Radboud hospital in the Dutch city of Nijmegen proposed to make a risk-analyses. This risk-analyses should be a GIS based simulation model of the Dutch province Noord-Holland. The simulation model should predict the malaria risk, influenced by changing environmental factors, in the future. This proposal was sent to the Wageningen University, which provided it as a thesis subject for a GIS student.

Before building the simulation model the design of the research had to be determined. A research proposal was made, containing the problem definition, research objectives and research questions. However during the research some research questions had to be changed and some research questions were added. The research proposal, its changes and the research area will be handled in this paragraph.

1.2.2 Research area

The research area is a province of the Netherlands; Noord-Holland. The province Noord-Holland is a coastal province in the northwest of the Netherlands and was the major focus of malaria (tertian, P. vivax).

Figure 1.2: The research area in the Netherlands

The province is surrounded by the North Sea at the west, the Waddenzee at the North and the IJsselmeer (Lake IJssel) at the east. The province Noord-Holland has a surface of 2672 km^2 and 2591837 inhabitants (*CBS website, 2004*). The population density is 969 inhabitants per km^2 and has 65 municipalities. Yearly 3552000 (*website province Noord-Holland, 2004*) people from foreign countries visit the capital city of Noord-Holland; Amsterdam. In total there are 136325 business establishments in the province Noord-Holland and 7330 of these are in the agricultural sector *(CBS website, 2004).*
The climate in the province Noord-Holland is more or less the same as in the whole of the Netherlands. The Netherlands has a moderate see climate with cool winters and mild summers. The average temperature at the coast is in the summer approximately 16°C and in the winter approximately 3°C. In the midland the average temperature in summer and winter are respectively 17°C and 2°C. Per year an average amount of 780 mm rain falls in the Netherlands *(website KNMI).*

1.2.3 Problem definition

GIS is a tool to make simulations and to analyse and visualize things. Such tool could be used for a risk analysis of the return of malaria in the province Noord-Holland. The question is how to use and in what way to use GIS in order to predict the return of malaria in Noord-Holland .

1.2.4 Research objective

The objective of this thesis is to predict the malaria risk in the Netherlands (Noord-Holland), with the help of a GIS-model.
The model will predict the risk of the return of malaria in the Netherlands. It will make use of historical as well as current data and should predict the future situation. The simulation model will be a model, which can change in time and space. Historical data will be used as calibration and validation data, and the output of the model will be the malaria risk (the future situation). By means of the model different scenarios can be simulated to calculate the risk of malaria when certain "environmental" changes take place.

1.2.5 Research questions

Research questions were made in order to get to know the disease malaria, its vector and the building of a simulation model. The subjects mentioned are the main research question, divided into more detailed research questions. To get to know the disease tertian malaria and its vector a literature study was done and personal information was given by supervisors. The basic needs for the malaria mosquito (vector) to exist, were investigated. These are sources for the blood meal of female mosquitoes, potential breeding places, shelters for mosquitoes and climate factors influencing the malaria mosquito.

What are the essential basic-needs of the malaria mosquito?

- Which hosts are preferred for the blood meal of the female malaria mosquito?
- What are the potential shelters for malaria mosquitoes?
- What are the potential breeding places for malaria mosquitoes?
- Which climate factors influence the existence/ development of the malaria mosquitoes?

For the disease malaria, caused by Plasmodium vivax, had to be determined which factors influence the parasite to develop insight the host. The factors influencing are climate, suitable hosts and existence of vectors. Also it is important to know where Plasmodium carriers come from, knowing that autochthonous malaria does not exist anymore in the Netherlands.

What are the basic- needs for Plasmodium vivax?

- What are the potential hosts for malaria vivax?
- Who are the potential malaria vectors?
- Who are the potential autochthonous malaria carriers?

To build the simulation model the research questions about the malaria parasite and its vector had to be answered. The input data of the model was determined by the answers gathered by the research questions. Calibration had to be done by data on malaria in history and the output of the model should be able to predict the malaria risk in the future under influence of changing climate and/ or environmental conditions.

Which data is needed to build a malaria risk simulation model for the province Noord-Holland?

- What are the basic-needs for Plasmodium vivax?
- What are the basic-needs of the malaria mosquitoes?
- Which geo-data is available needed of the province Noord-Holland?
- Which data is needed of malaria in time?
- What will be the influence of climate changes on malaria-risk?
- What will be the influence of environmental changes on the malaria-risk?

1.3 Previously done research

An example of previously done research is the research of Takken, et al.(2002), in the Dutch province Zuid-Holland. This research is done for the ministry of traffic and waterworks of the province Zuid-Holland. (Ministerie van Verkeer en Waterstaat, Directoraat-Generaal Rijkswaterstaat, Directie Zuid-Holland). The objective of this research is to determine whether endemic malaria can return in the west of the Netherlands.
The conclusion is briefly summarized: Because of the low density of Anopheles atroparvus and the recorded zoöphilic feeding behaviour of An. messeae, there is suggested that there is currently no risk that endemic malaria will return in The Netherlands (*Takken et all, 2002).*

2 Malaria mechanism

2.1 Introduction

Until 1960 malaria occurred endemic and sometimes in the form of epidemics in the Netherlands. Mosquitoes that can transmit the disease malaria (the plasmodium) still appear in the Netherlands. In this chapter the future malaria, the malaria cycle and the vectors transmitting the disease plasmodium (malaria mosquitoes), will be elaborated.

2.2 Malaria background

Epidemics of malaria in the Netherlands occurred in the years 1857, 1880, 1900, 1920, 1930 and 1933-1940. In the years 1946-1948 the last epidemic occurred in the Dutch province Noord-Holland. After this last epidemic only a few endemic cases of malaria occurred until the year 1959. In 1970 the Netherlands was officially declared malaria free by the World Health Organization. In history malaria mosquitoes lived inside the houses of families; on ceilings and inside stables that were connected to the houses. Due to water surface pollution (larvae develop on the surface water) by phosphates and spraying with insecticides in the houses and stables, the malaria mosquitoes disappeared. The plasmodium causing malaria could not be transmitted anymore due to low densities of its vector (malaria mosquitoes). The vector of malaria in the Netherlands was *Anopheles atroparvus*. *Anopheles messeae* is a strongly related mosquito that also exists in the Netherlands but which did not transmit malaria. The parasite transmitted by *An. atroparvus* is *Plasmodium vivax*, which occurs in (sub) tropics and earlier also at temperature climates. The official name of the form of malaria caused by Plasmodium vivax is *malaria tertiana*. The causing agent and the transmission of malaria were discovered at the end of the 19th century. Malaria is an infection blood-disease. The disease malaria characterises itself by enlargement of the spleen as well by serious fever attacks every other one or two days (Kraan, H, 1969).

Since 1970 the water quality is highly improved as a result of the law for pollution of surface waters, which was introduced in 1970. This law was followed up by the prohibition on the use of phosphates in synthetic soaps in 1988. As a result of these two legislations the quality of the Dutch surface water is highly improved. Due to the improved quality of the surface water and reconstruction of nature areas the mosquito densities of *An. atroparvus* and *An. messeae* is assumed to grow again. In theory it is possible that the Dutch malaria mosquito will get infected by malaria. In 1997 a woman was infected by a native malaria mosquito, with *Plasmodium vivax,* in Italy. The native mosquito was infected with malaria by the neighbours of the woman, who were just returned from their holiday in India *(Takken et al., 2003*).
In the Netherlands a case of secondary malaria caused by imported *P. vivax* is known. A soldier returned from the war in Korea took a *P. vivax* infection with him and a boy in the same village (in Noord-Brabant) was infected. The P. vivax parasite was transmitted by a native malaria mosquito.
Imported malaria cases have also been reported in Belarus, Bulgaria, Greece and the Republic of Moldova in recent years *(WHO website, 2004).*
A country like Turkey is an example of an European country suffering from endemic malaria. In 1925 a malaria control program was launched in Turkey, due to spraying with DDT and medical treatment the disease was more or less under control in 1968. Since 1970 only cases of *Plasmodium vivax* occurred endemic in Turkey, before *Plasmodium falciparum* was the predominant species. In 1971 the number of malaria cases began to increase again. In 1977 an epidemic number of 1155121 cases of *P. vivax* malaria were reported and in 1983; 66673 cases of malaria were reported. The highest number of cases reported in this decade was a number of 84321 cases registered in 1994. From 1997 the number of malaria cases were decreasing again. *(WHO website, 2004).* About 15 million of people live in the endemic area.

A lot people originating from Turkey live in the Netherlands and regularly visit Turkey. In the epidemic years of malaria for the Netherlands import of malaria from Turkey did exist, however no cases of secondary infection are known (according to J.P. Verhave).

2.3 Malaria mosquitoes

Anopheles is the only genus of mosquitoes that can transmit malaria on humans.
Worldwide there are approximately 470 different species of *anopheline* mosquitoes, at least 60 of these 470 species are acknowledged to be malaria vectors.
In the Netherlands only tree species of the genus *Anopheles* occur. These are *An. maculipennis s.s.*, *An. atroparvus* and *An. messeae*. *An. maculipennis s.s.* only can be found in the eastern part of the Netherlands, the others can be found in a broader area. *An. atroparvus* and *An. messeae* can especially be found in the coastal provinces like Noord-Holland, Zuid-Holland and Zeeland.
According to Takken *et al., 2003; Anopheles atroparvus* is the only mosquito that could be seen as a malaria vector in the Netherlands. *Plasmodium vivax* can also develop in *An. messeae*, but this mosquito is not acknowledged as a significant malaria vector in the Netherlands, because of its different behaviour.
In this research *An. atroparvus* as well as *An. messeae* are assumed to be vectors of *Plasmodium vivax.* When there is spoken about “Malaria mosquitoes”, species *An. atroparvus* and *An. messeae* are meant. State variables, which are important for the malaria cycle and for the existence of malaria mosquito, have been determined.
Climate, habitat and demographics are important factors for the existence of malaria mosquitoes, the development of the plasmodium and the transmission of malaria. The variables of importance are elaborated in c*hapter 3 Conceptual model* and in *chapter 4 Case study Noord-Holland.*

2.4 Plasmodium

2.4.1 Plasmodium vivax

Human plasmodia are; *Plasmodium vivax, Plasmodium ovale, Plasmodium malariae and Plasmodium falciparum.*

Plasmodium falciparum and *Plasmodium vivax* are the main parasites that can cause malaria *(Takken et al., 2003).* The mosquito *Anopheles atroparvus* is able to transmit *P. vivax*. The type of *P. vivax* in the Netherlands has a long incubation time of approximately 8 months. The tropical forms of *P. vivax* have an incubation time of 2-3 weeks and can be found in countries like: Indonesia, Thailand, India, Pakistan, Afghanistan, Turkey and Latin America. *P. vivax* is less common in tropical Africa and especially in West Africa.

The only cases of people carrying the *P. vivax* found in West-Europe after 1960, are people who were suffering from the so called "imported malaria".

When summers are long and hot there is a possibility that this imported *P. vivax* can be taken up and carried by *An. atroparvus* mosquitoes and possibly also by *An. messeae* mosquitoes. In this case it is possible that native malaria mosquitoes will transmit the plasmodium from one person to another (secondary cases).

Yearly approximately 750 cases of imported malaria are reported into the Netherlands, 40 % of these cases are infections with *P. vivax (Hest, et al., 2001).*

2.4.2 Life cycle malaria in Human

Malaria is an infectious disease caused by a parasite that is transmitted by the malaria mosquito. Infection with the malaria parasite takes place by means of the saliva of the malaria mosquito. The parasite cycle is described by Van der Kaaden (1999), in figure 2.1 the cycle is explained. The saliva of the malaria mosquito carrying the parasite contains sporozoïtes. This sporozoïtes will infiltrate in the blood. In less than a hour the sporozoïtes have disappeared from the blood and can only be found in the liver as hypnozoïtes. After a latency period of six to nine months the hypnozoïtes will develop and damage the liver cells. The nuclei of the hypnozoïtes will divide and finally the hypnozoïtes will fragmentate. The fragmentated pieces together with the cytoplasm will form merozoïtes. The host cell will be destroyed, the merozoïtes enter the blood and infiltrate in the red blood cells. They will feed themselves with haemoglobin. During the digestion the parasite produces a pigment, this is an iron-containing residue of digested haemoglobin. The parasites in the red blood cells will split up again and will form new merozoïtes. The host (the red blood cells), will eventually be destroyed. The parasites will get in contact with other red blood cells and the whole cycle will repeat again.

The fever attacks, which are caused by the parasite, are the result of the by-products of destroyed blood corpuscles and the protein-materials odd to the human body.

The number of parasites will multiply logarithmic proportional and destroys the red blood corpuscles. During the infection sexual propagating organisms will be formed out of the merozoïtes. These organisms are male and female gametocytes. These gametocytes do not multiply and remain circulating in the blood until they get destroyed, or until the carrier is bitten by a (female) malaria mosquito.

2.4.3 Live cycle malaria in mosquitoes

The gametocytes enter into the stomach of the mosquito. Influenced by changing acidity and temperature the gametocytes develop in the stomach of the malaria mosquito. The gametocytes develop into gametes in the midgut of the *Anopheles*. The male (micro) gametes will fertilize the female (macro) gametes and a zygote will be formed. After the exflaggellation of the male and fertilization of the female gamete, the sexual cycle takes 16 days at 20 ºC and 8 – 10 days at 28 ºC (*Plasmodium vivax)*. Below 15 ºC the completion of the sporogonic cycle is unlikely *(M. Gilles, Warrel, A.D, 1993)*.
The zygote will penetrate the wall of the midgut and sporozoïtes are developed, these sporozoïtes will infiltrate into the salivary glands of the mosquito. The sporozoïtes can enter the blood of a next victim during the next "blood meal" of the mosquito. The whole cycle repeats again and again and more people can be infected.

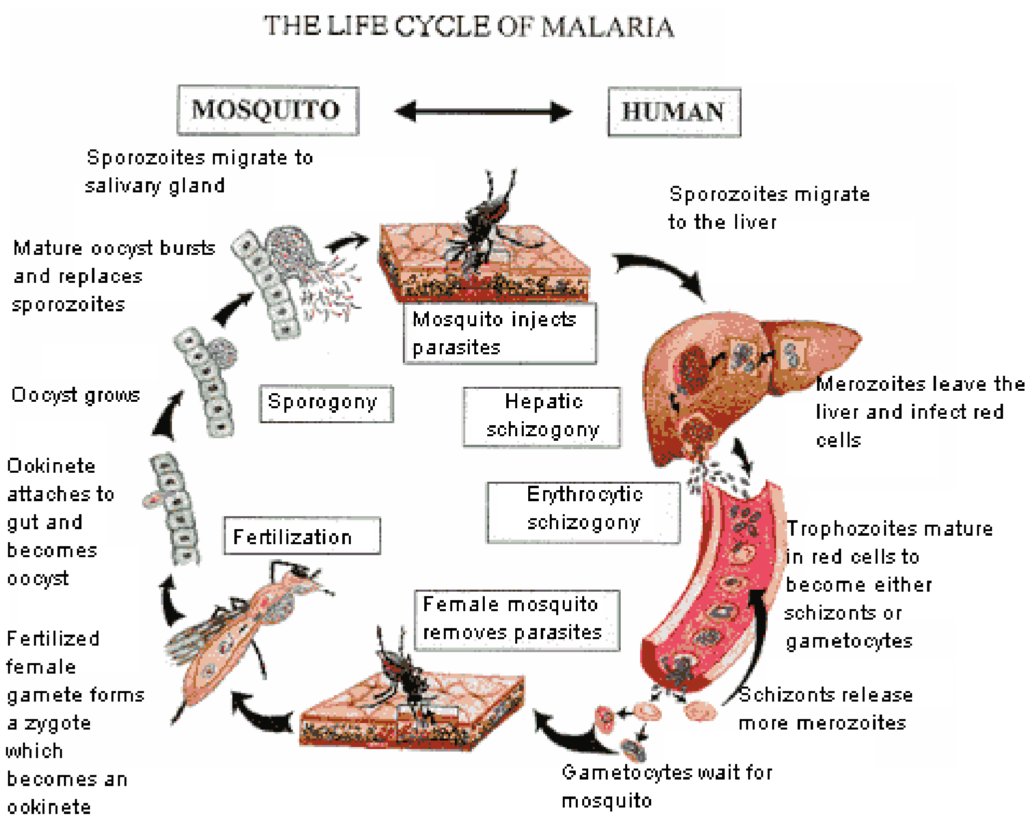


Figure 2.1: Life cycle of malaria (website WHO).

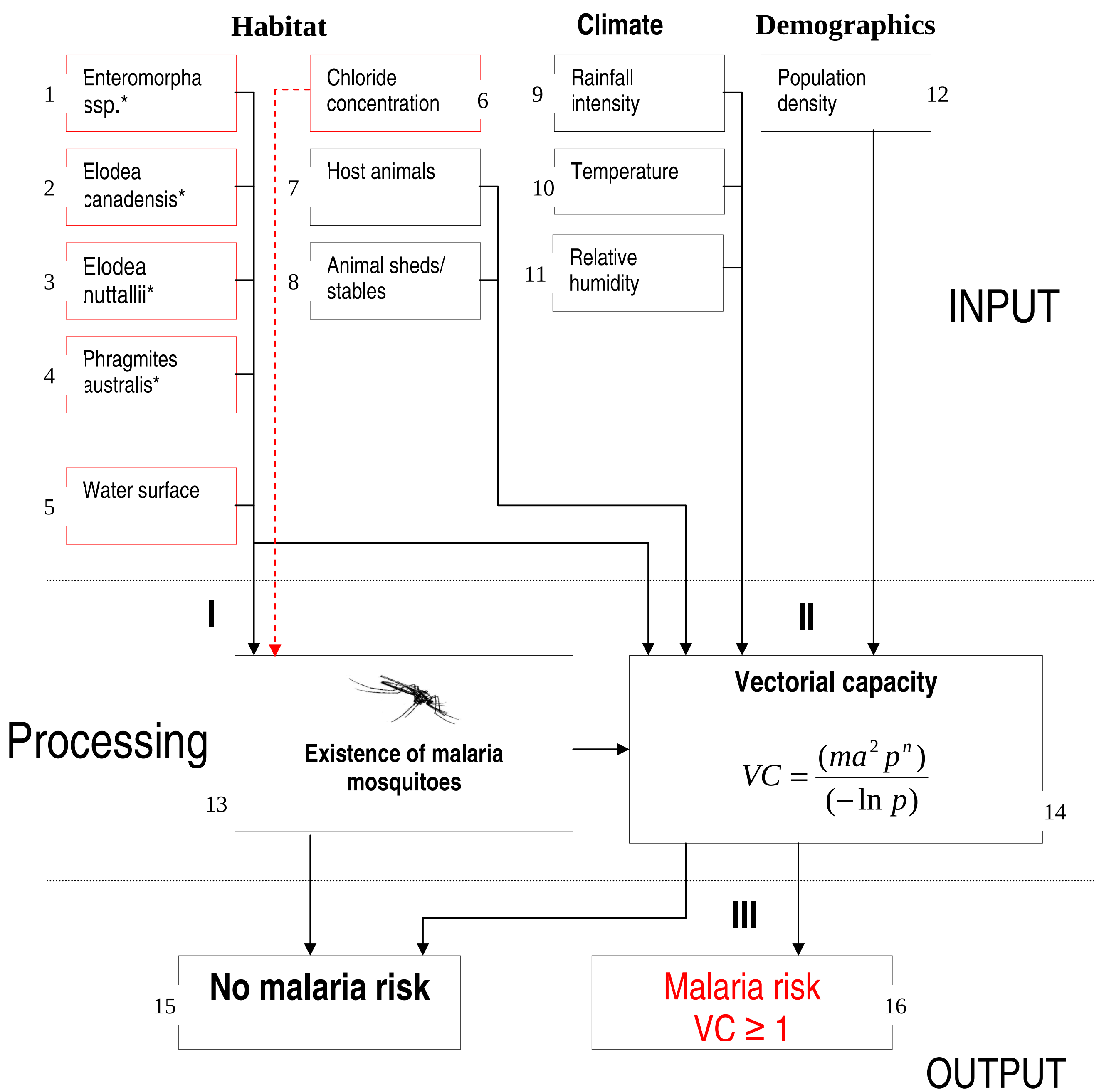
3 Conceptual model

3.1 Introduction

In this chapter the conceptual model is explained in detail. The model consists of twelve input parameters (state variables); four kinds of aquatic vegetation, km^2 water surface per municipality, chloride concentration, host animals per km^2 per municipality, animal sheds/ stables per km^2 per municipality, rainfall intensity, air temperature, relative humidity and population density per km^2 per municipality. The area of interest for the model is the Dutch province Noord-Holland. The model, which has two spatial dimensions, is interactive. The model is interactive because the user can change the state variables and the weights of the state variables in the model.
In the model it is possible to run different scenarios to predict the malaria risk in the future. It is possible to change the state variables for every year and to change the weights of some state variables in the model.

The structure of the conceptual model is shown in paragraph 3.2. A description of the model is given in paragraph 3.3, Paragraph 3.4 explains the multi criteria evaluation.

3.2 Schematic representation of the model



**The different plant species will be mentioned as one group; 'Aquatic vegetation'*

Figure 3.1: Schematic representation of the model

3.3 Description of the model

The working of the model is explained in this paragraph. In order to run the model, data has to been gathered for the years of which the malaria risk is going to be calculated. The data to be gathered is; climatic, habitat and demographic data. These parameters will serve as the input data for the model. The input parameters can be mentioned as the state variables, which are variables that are part of the system. Below the schematic representation of the model is explained in steps:

INPUT

- The first step is to gather the right input data for the different parameters (See data group and state variable of table 3.1 below).
- The second step is to put the gathered data in the right format (See Unit of table 3.1 below).

Data group	**State variable**	**Number**	**Unit**
Habitat	Aquatic vegetation	1,2,3,4	Present / not present
Habitat	Water surface	5	m^2 water surface per km^2 per municipality (Ditches <3m wide)
Habitat	Chloride concentration	6	mg/l
Habitat	Host animals	7	Amount of animals per km^2 per municipality
Habitat	Animal sheds/ stables	8	Amount of sheds/ stables per municipality (survey)
Climate data	Rainfall intensity	9	Mm/ day
Climate data	Temperature	10	Average air temperature ºC/ month
Climate data	Relative humidity	11	(Saturation) %
Demographics	Population density	12	Population per km^2 per municipality

Table 3.1: Input data

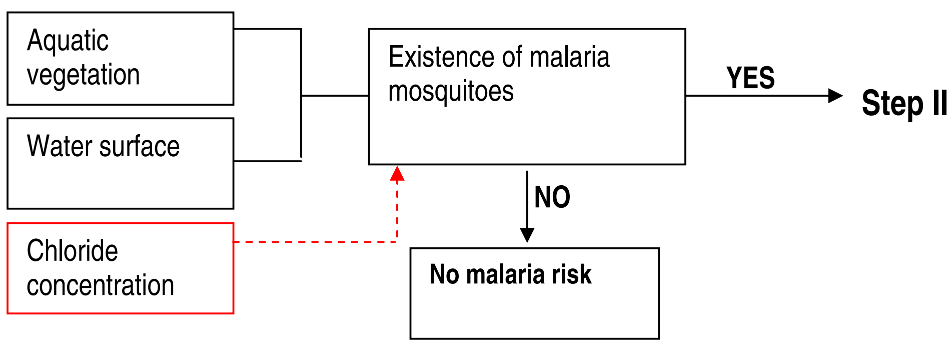
- The third step is to enter the data into the model.

PROCESSING

I. The first step of the model is very important, in this first step the aquatic vegetation, km^2 of water surface and the chloride concentration are being processed. According to *W. Takken (a malaria mosquito specialist of the Wageningen university)* it is assumed that larvae only can exist under specific conditions; for every municipality there has to be more than 100 m^2 of ditches (water surface of ditches <3m wide) per km^2, one or more of the four different types of aquatic vegetation have to be present and the chloride concentration has to be lower than 2500 mg/l. If the state variables agree upon these conditions, larvae can exist and the processing can continue. If one of the state variables does not conform to the conditions mentioned above, no larvae can exist and no malaria can occur. The output of the model will than be; '*no malaria risk*'. Till recently there was assumed that malaria mosquitoes prefer brackish water, in further research no evidence to substantiate this assumption has been found. Nevertheless the chloride concentration has been incorporated in the model.

The user can easily change the importance of the chloride concentration in the model as he or she wishes.

Processing step I.



II. The next formula is used in the model. It is used to calculate the probability an infectious mosquito actually transmits infection when biting.

Formula; $$VC = \frac{(ma^2 p^n)}{(-\ln p)}$$ *(Garrett-Jones, 1964)* [1]

VC = The number of secondary cases which arise from the bites taken by all mosquitoes on one infectious person in one day.
m = Number of mosquitoes per person.
a = The daily biting rate of a female mosquito on a man (determined by the Human Blood Index (HBI) * the feeding frequency).
p = Daily mosquito survival rate.
n = Extrinsic incubation period (the time taken for plasmodia to mature to infectious sporozoites in mosquito).

*The number of secondary cases, which arise from the bites taken by all mosquitoes on one infectious person per day (**VC**)*
The model will calculate the vectorial capacity. The vectorial capacity will represent the malaria risk.

*Number of female mosquitoes per person (**m**)*
This variable is determined by the state variables; population density, m^2 of water surface and the rainfall intensity. The user can fill in how many larvae exist per m^2 of water surface per km^2 per municipality. The model calculates the number of female mosquitoes per km^2 per municipality per month[1]. If rainfall has exceeded an amount of 20 mm/ day, a lot of larvae will be flushed away. The user can fill in the percent of larvae dying due to rainfall. The number of female mosquitoes per km^2 per municipality will be derived by the number of larvae per m^2 per km^2 per municipality minus the percent of larvae dying due to rainfall.
To derive the number of female mosquitoes per person *(**m**)*, the number of female mosquitoes per km^2 per municipality, has to be divided by the number of people per km^2 per municipality.

*The daily biting rate of a female mosquito on a person (**a**)*
This variable is determined by the Human Blood Index, which represents the biting rate of mosquitoes on humans times the biting frequency. In this index a value of 0,05 is given as the Human Blood Index for the *Anopheles messeae* mosquito.
This value is taken for as well the *Anopheles messeae* as the *Anopheles atroparvus* mosquitoes. A biting frequency of once in the five days is taken, this results in a biting frequency of 20%. For as well the Human Blood Index as the biting frequency the values can be changed by the user.

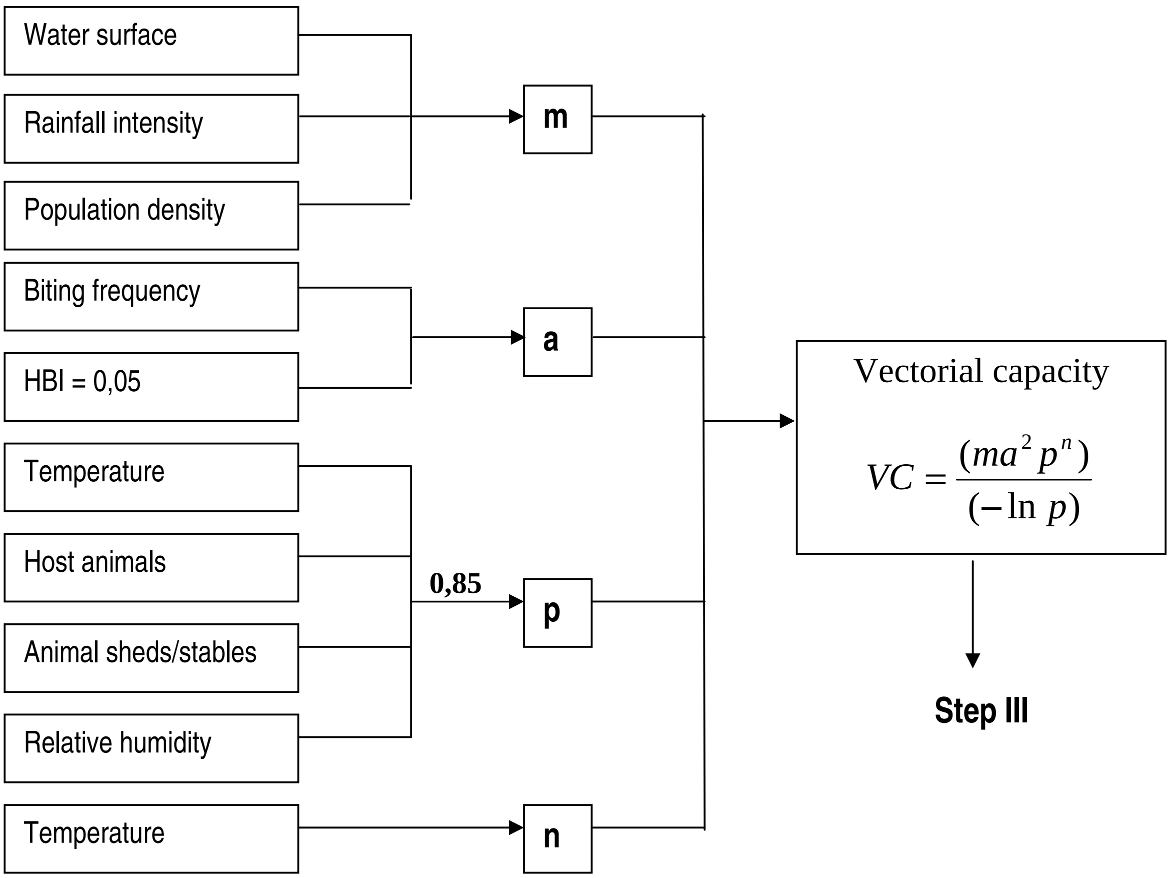
*Daily mosquito survival rate (**p**)*
The daily mosquito survival rate is provided by *W. Takken*. The value of the daily mosquito survival rate can be set on 0,85. This value will be determined by the state variables; host animals, animal sheds/stables, temperature and relative humidity. The user will subscribe weights to these state variables. These weights are determined using the ranges mentioned in *table 3.3; State variable ranges*, the weights are determined using multi criteria evaluation (see paragraph 3.4; multi criteria evaluation).

[1] Calculation of the amount of female mosquitoes per km^2 per municipality (Takken et. al., Royal Swedish Academy of sciences, 2002).
Water surface per m^2 per km^2 per municipality * 0.3 (30% of the water surface is suitable for mosquito larvae) * number of larvae per m^2 * 0.8 (80% of the larvae will survive) = daily emerging adult mosquitoes per km^2 water surface per municipality / 2 = daily emerging female mosquitoes per km^2 water surface per day * 30 days.

*Incubation period (**n**)*

The extrinsic incubation period of *Plasmodium vivax* can be determined by the state variable temperature. The incubation period of Plasmodium vivax is 8 till 10 days at a temperature of 28 ºC. At a temperature of 20 ºC the incubation period is 16 days and from 15 till 20 ºC the incubation period is approximately 17 days (Gilles, M , A. Warrel, 1993).The model will determine the incubation time by temperature ranges. The model will ascribe the incubation period as followed: incubation time is 17 days if the average temperature is ≥ 15 ºC and < 19 ºC, if the average temperature is ≥ 19 ºC and < 21ºC the incubation time is 16 days. If the average temperature is ≥ 21ºC and < 25 ºC the incubation time is 14 days and the incubation time is 10 days if the average temperature is ≥ 25ºC and < 28 ºC.
The values for the incubation time and the temperature ranges can be changed by the user.

Processing step II.



OUTPUT

The output of the model represents the malaria risk of various locations (in Noord-Holland). The higher the vectorial capacity *(**VC**)*, the higher the malaria risk. The vectorial capacity is assumed to be equal to the number of malaria cases (if the plasmodium exist). So a vectorial capacity of one represents one malaria case.

3.4 Multi criteria evaluation

3.4.1 The advantage of multi criteria evaluation

Geographical information systems are a powerful tool in managing and analysing spatial data. The disadvantage of GIS is that it has no tool for dealing with criteria evaluations. In order to weight the different state variables, a multi criteria evaluation has to be done. This multi criteria evaluation supports the GIS-system used. With the help of the multi criteria evaluation the state variables will get a weight. The weight represents the degree of importance of the state variable in relation to the existence of the malaria mosquito. The weights determined can be used in the model. *(See appendix 1 for an explanation of multi criteria evaluation).*

3.4.2 Multi criteria evaluation for the state variables

The multi criteria evaluation will be done for the four state variables that determine parameter ***p*** (daily mosquito survival rate) in the model formula. These state variables are; host animals, animal sheds/stables, temperature and the relative humidity.
The first step of the multi criteria evaluation method is to rank the different state variables. The state variables will be ranked by importance on the existence of the malaria mosquito.

State variable	**Importance**
Host animals	2
Animal sheds/stables	2
Temperature	1
Relative humidity	1

Table 3.2: Result of ranking state variables

Table 3.3 shows the suitability for existence of malaria mosquitoes at a certain value of the state variables. The ranges of the four state variables in italic mentioned in table 3.4 are used to weight the state variables.

State variable	**Not suitable**	**Suitable**	**Optimum**
Chloride concentration (mg/l)	<100 >2500	100-300 1200-2500	300-1200
Host animals (animals/km²)	*0*	*1-10*	*>10*
*Animal sheds/ stables per km² per municipality**	*0*	*1-10*	*>10*
Rainfall intensity (mm/day)	>20		<20
Air temperature (ºC) *(for P. vivax)*	<15 >28		15-28
Air temperature (ºC) (for An. atroparvus and An. messeae)	*<10*	*10-20*	*20-30*
Relative humidity (%)	*<60*		*>60*
Population per km² per municipality	-	-	-

**Values of animal sheds/ stables have to be investigated more in future research; current values are just an indication.*

Table 3.3: State variable ranges

Table 3.4 shows the importance of the state variables as a percentage. The climatic state variables temperature and relative humidity are determined as the most important state variables in relation to the daily mosquito survival rate; together they have an importance of 75%. The habitat state variables host animals and animal sheds/ stables are determined to be less important. Together they have an importance of 25%.

State variable	Importance (%)
Temperature	37.5
Relative humidity	37.5
Host animals	12.5
Animal sheds/ stables	12.5

Table 3.4: Importance of state variable in %

Table 3.5 shows the weights subscribed to the parameters. If one of the state variables has a value of zero (not suitable); the daily mosquito survival rate will be zero, which will end up into the output; no malaria risk. When all state variables have a value, which lays into the suitable or optimal range, they will get a weight and a daily mosquito survival rate of 0.85 will be the result.

State variable	Not suitable	Weight	Suitable/ optimal	Weight
Host animals	0	0	1-10 / >10	0,94*
Animal sheds/ stables	0	0	1-10 / >10	0,94*
Relative humidity	<60	0	>60	0,98*
Temperature	<10	0	10-20 / 20-30	0,98*

Table 3.5: Weights of the state variables

*The outcome of all weights has to be 0.85 = weight host animals * weight animal sheds/ stables * relative humidity * temperature.
(0,85 is the daily mosquito survival rate according to *W. Takken*).

3.4.3 Elaboration of the multi criteria evaluation

The multi criteria evaluation done in this paragraph is an example. The weights for the mentioned parameters have to be determined by a malaria expert. The malaria expert has to determine more values for the daily mosquito survival rate, so that the daily mosquito survival rates and their weights could be determined for not suitable, suitable and optimal state variables. The multi criteria evaluation is of importance for the user, the method followed is necessary for the model building and the user can change weights into the model to optimise the model.

4 Case study Noord-Holland

4.1 Introduction

In this chapter the required input data is discussed for the model twelve different types of input data are used. These input data are: aquatic vegetation (*Enteromorpha ssp., Elodea canadensis, Elodea nuttallii, Phragmites australis),* km^2 water surface, chloride concentration, host animals, animal sheds/ stables, rainfall intensity, average temperature, relative humidity and population density.
The reasons for using these types of state variables will be explained and the data sources will be mentioned. The format of the collected data, their conversion and the problems encountered during data retrieving will be discussed.
The research area for which the mentioned data are gathered is the Dutch province Noord-Holland. In *figure; 4.1* a map of the research area; located in the Netherlands is shown and the research area is shown with buildings, water and municipality borders.

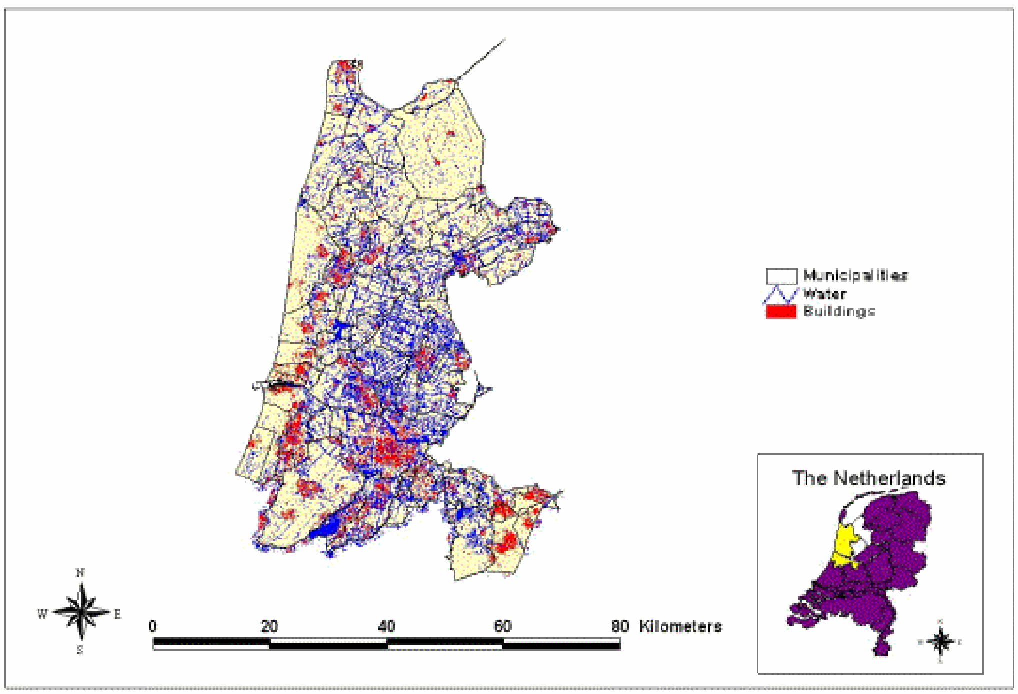


Figure 4.1: The research area.

4.2 Relevance of the state variables

After considering the aim of the model, *making a malaria simulation model that will predict the malaria risk using different scenarios*, the state variables (input parameters) have been determined. The state variables, which are selected, are of great importance on the malaria cycle. Which state variables are used and why they are used, is explained in this paragraph.

The input data can be arranged in three classes; habitat data of the malaria mosquitoes, climatic data and demographic data. The class; *habitat of the malaria mosquitoes*, consists of the state variables; km^2 water surface, aquatic vegetation (*Enteromorpha ssp., Elodea canadensis, Elodea nuttallii and Phragmites australis*), chloride concentration, host animals, and animal sheds/ stables. The class *climatic data* consists of the state variables; rainfall intensity, average temperature and relative humidity. The class *demographics* contains the population density *(See appendix 2 for all state variable data).*

Aquatic vegetation

The presence of the water plant species *Enteromorpha ssp., Elodea canadensis, Elodea nuttallii* and *Phragmites australis* are indicators for the existence of larvae of *An. atroparvus* and *An. messeae*. *An. atroparvus and An. messeae* have a strong association with floating and submerged vegetation in the water (Takken *et al*, 2003), they lay their eggs on the floating vegetation in which the larvae have their biotope. The plant species mentioned above are common water plant species in the Netherlands.
Few mosquito larvae will be found in ditches without vegetation or in ditches that are densely vegetated with for example duckweed *(Lemna ssp.)*.

M^2 of water surface

Larvae of malaria mosquitoes develop in small ditches. These ditches have a maximum width of 3 meter. The amount of water is of great importance on the amount of larvae that can develop. The more water (small ditches) appropriate for the mosquitoes the more larvae which can develop.

Chloride concentration

Till recently it was assumed that *An. atroparvus* mosquitoes prefer brackish water with a chloride concentration that ranges between 1000 mg/l and 2500 mg/l (Kaaden, J.J. van der, 1999). Later on, no evidence has been found to substantiate this; nevertheless the parameter has been incorporated in the model.

Host animals

Malaria mosquitoes are strong zoophiles; they prefer the blood of animals above that of humans. They usually get their blood meals from; horses, sheep, pigs and cows. Female mosquitoes need a blood meal to grow their eggs.

Animal sheds/ stables

Malaria mosquitoes prefer dark, badly ventilated places. Old farms with cattle and small stables/sheds for horses, sheep, pigs and cows are therefore suitable shelters for malaria mosquitoes. Nowadays farms have stables that are better ventilated and have more light intrusion. These kind of stables are less suitable as shelters for the mosquitoes.

Rainfall intensity
Rainfall is an important climatic parameter. Mosquito larvae develop in small ditches and puddles. In case of high quantity of rainfall on one day, larvae on top of the floating vegetation will be flushed away. The amount of larvae will decrease significantly. Female mosquitoes lay new eggs just after this heavily rainfall, these larvae develop in 6 till 3 weeks depending on the water temperature *(Takken et al , May 2002.)*
The decrease of mosquitoes by this rainfall will cause a gap in the generation.
There are 3 to 4 generations of mosquitoes per year *(Swellengrebel & de Buck 1938).*

Temperature
Temperature is of great importance on the development of the Plasmodium (the protozoon that causes the disease malaria) into the malaria mosquito. The minimum temperature at which the sporogonic cycle of *Plasmodium vivax* completes into the malaria mosquitoes is 15 ºC. Higher temperatures cause a shorter incubation period. The temperature is also of importance on the development of the malaria larvae. The larvae of the malaria mosquitoes develop at aquatic temperatures higher than 10 (ºC). Higher temperatures will cause more successing generations.

Relative humidity
The relative humidity is of importance for the development of the malaria mosquito and the Plasmodium. The relative humidity in the Netherlands is suitable for the existence of the malaria mosquito, but the state variable is taken into account in case the user of the model would like to change this state variable for climate scenarios.

Population density
The human population density is an important state variable. When a person gets infected in a dense populated area the chance of transmission of the disease to other individuals, is larger. The female mosquitoes need blood to feed their eggs, in a densely populated area the chance on a human ''blood meal'' is bigger, for the malaria mosquitoes.
However in densely populated cities less mosquitoes will exist because no zoöphilic blood donors, which is preferred by the malaria mosquito, will exist there.

4.3 Data sources and format

Aquatic vegetation

The data group aquatic vegetation contains the following species; *Enteromorpha ssp., Elodea canadensis, Elodea nuttallii* and *Phragmites australis.* For the year 1934 there is only data available for *Enteromorpha ssp., Elodea canadensis* and *Phragmites australis. Elodea nuttallii* is another variety of the *Elodea* genus. *Elodea nuttallii* was also considered to be important for the research, because it is very similar to *Elodea canadensis*. Since *Elodea canadensis* is very rare, *Elodea nuttallii* has been incorporated in the research for the years 1992 and 2003, because more data about this plant type is available.

The data for the vegetation types of the year 1934 are taken from the report of G. van der Torren. In the report is mentioned whether the type of vegetation is present or not on the different sample locations.

For the years 1992 and 2003 the same database has been used. The data was taken from the website of the HHNK (Hoogheemraadschap Hollands Noorderkwartier). At the website (http://194.151.97.59/) it is possible to choose a parameter of which data is required. These parameters were taken at locations in the management area of the HHNK. The vegetation data was taken in shifting order; the sample location shifted every year. For the years 1992 and 2003, data of five following years was taken to derive vegetation data for the whole research area. For vegetation data of the year 1992, the years 1990, 1991, 1992, 1993 and 1994 have been taken. The years 1999, 2000, 2001, 2002 and 2003 have been taken to represent the vegetation data of the year 2003.

M^2 water surface

Km^2 water surface will be measured by a visual interpretation of the research area. This has only has been done for the year 2003. For 2003 it has been done by visually interpretating the topographical map 1:50000 (top50) of 1999 ditches smaller than three meter are shown on this map. To make this visual interpretation of the ditch density spatial, the ditch density is determined in m^2 of water surface per km^2 per municipality. For the year 1934 a rough estimation of the m^2 water surface per municipality is done by comparing the water surface of 2003 with the historical map of 1900. The maps, which are used for visual interpretation, are gathered from the geodesk of the University of Wageningen.

Chloride concentration

The chloride concentration of the surface water of the research area for the years 1934, 1992 and 2003 has been measured in mg/l.

The chloride concentration for the year 1934 ranged from 35 mg/l to 7272 mg/l. These chloride concentrations were measured by G. van der Torren and they were published in a database in his report; "*De zoografische verspreiding van Anopheles maculpennis messeae in westelijk Nederland met het oog op 'Species-assaineering'* ".

In the year 1992 the chloride concentration ranged between 55 mg/l and 8275 mg/l, this chloride data has been derived from a historical database of the province Noord-Holland. A shape file with the locations of the sample points was included. The database and shape file were provided by the HHNK. In the year 2003 the chloride concentration of the surface water ranged between 57 mg/l and 2746 mg/l. The chloride data of 2003 was also provided by the HHNK. The HHNK owns a large database with data of several locations in the province Noord-Holland on the quality of surface water in their management area. This data can be found on the following website; http://194.151.97.59/.

Host animals
The state variable host animals represent the blood meals of the mosquitoes. Mosquitoes prefer blood from animals. Horses, sheep, cows and pigs are the animals where the malaria mosquitoes can get their blood meal from. Data about host animals is not gathered yet and can be filled in by the user later on.

Animal sheds/ stables
Small badly ventilated sheds/stables represent this state variable. These kinds of sheds/ stables are mostly no part of commercial farms. Data about this state variable is not gathered yet and can be filled in by the user later on.

Rainfall intensity
Rainfall data in mm per day and the duration of rainfall in hours can be found at the KNMI (Royal Dutch Meteorological Institute) website. The website of the KNMI contains historical meteorological data for every day of the year. The required data for the years 1934, 1992 and 2003 is only available at the database of the meteorological station of *De Bilt*. This database has been used to collect data for the model. Although the meteorological station of *De Bilt* is located at reasonable distance of the study area, the data is considered useful and representative. For the three different years the average rainfall per day for the months March till September is taken. It is assumed that the rainfall intensity is equal for the whole research area.

Temperature
Like rainfall, the temperature data can also be found on the KNMI website. The average temperatures for every month of the years 1934, 1992 and 2003 are given in °C. For the model, the average monthly temperatures in °C, are needed for the months March until September of the years 1934, 1992 and 2003. The required data is available at the database of the meteorological station *The Bilt*. To derive the aquatic temperature, which is different from the air temperature, an assumption has been made. There is assumed that the aquatic temperature is 2,5°C higher than the air temperature. This is assumed according to a comparable research in Zuid-Holland where is stated; on average, at the surface, the temperature of the water was 2,5°C higher than that of the ambient air (Takken *et al* , May 2002.)

Relative humidity
The relative humidity is assumed to be suitable for mosquitoes in the Netherlands. Malaria mosquitoes prefer a relative humidity of 60%. Most of the time the relative humidity is 60 % or higher in the Netherlands.

Population density
Data about the population density can be found at the CBS. The amount of people per municipality, for the years 1992 and 2003, have been taken from the website of the CBS and the number of people per municipality for the year 1934 were provided by the *Noord-Hollandsarchief.*
In order to calculate the population density for each different year, the boundaries of the municipalities have to be known. The boundaries of the municipalities, the number of municipalities and even the existence of some municipalities differ for every year of interest.
The boundaries of the municipalities for the year 2003 have been provided by the geodesk of the Wageningen University. These boundaries of 2003 have been used to make the population per municipality of the year 2003 spatial as well as to make the population per municipality of the years 1992 and 1934 spatial. Eventually the data is processed into population per km^2 per municipality.

Data	Sources		
	1934	1992	2003
Water surface	-	-	❑ Geodesk (visual interpretation of topographical map)
Aquatic vegetation	❑ Published report of G. van der Torren	❑ HHNK (website with HHNK database, quality surface water)	❑ HHNK (website with HHNK database, quality surface water)
Chloride concentration	❑ Published report of G. van der Torren	❑ HHNK (database of the province Noord-Holland)	❑ HHNK (website with HHNK database, quality surface water)
Host animals	-	-	-
Animal sheds/ stables	-	-	-
Rainfall intensity	❑ KNMI (website with meteorological data)	❑ KNMI (website with meteorological data)	❑ KNMI (website with meteorological data)
Aquatic temperature	❑ KNMI (website with meteorological data)	❑ KNMI (website with meteorological data)	❑ KNMI (website with meteorological data)
Relative humidity	❑ Assumed to be 60%	❑ Assumed to be 60%	❑ Assumed to be 60%
Population density	❑ Noord-Hollandsarchief	❑ CBS-website	❑ CBs-website

Table 4.1 Model data and source

4.4 Data processing

Data processing has to be done before the state variables can be used for the simulation model. Often the data has to be made spatial and calculations have to be made before the data can be used. In this paragraph the processing of the thematic data into spatial data is described. Other data transformations, like data calculations, are also described.
The input grids of the model are the province border, municipality borders, the four vegetation types and the chloride concentration is an optional input grid. These grids have a grid resolution of 500 by 500 meter. The other data is put into the model by means of a database or manually filled in by the user.
The database file contains the number of inhabitants per municipality, municipality area, number of host animals per municipality, number of animal sheds and stables and the m^2 water surface (ditches <3 m wide) per municipality. The state variables that have to be filled in manually by the user are; relative humidity per month, average temperature per month and a dying factor for mosquito larvae determined by the rainfall intensity.

Aquatic vegetation

The vegetation data for 1934 is taken from the report of G. van der Torren, just like the chloride data of 1934. The shape file of the different vegetation types show only the locations at which a vegetation type is present. For each vegetation type a different shape file has been made. For the year 1934 this means that there are three different shape files; *Enteromorpha ssp., Elodea Canadensis* and *Phragmites australis*.
For the years 1992 and 2003 data from the HHNK have been used. A shape file with the sample points is included with the data. Vegetation data for *Enteromorpha ssp., Elodea canadensis, Elodea nuttallii* and *Phragmites australis* was available. The data of these vegetation types are included in the attribute table of the shape file. The shape file only shows the sample points where vegetation is present. Just like in 1934 for each vegetation type one shape file has been made. The final step for the year 1934 as well as 1992 and 2003 is to convert the shape file to raster.

M^2 water surface

The m^2 of water surface for the province Noord-holland will be determined as the *m^2 water surface per km^2 per municipality* for the years 1934, 1992 and 2003. First the km of ditches smaller than 3 meter wide per municipality were estimated from topographical maps in order to make the data spatial. An average ditch width of 2 meters was taken. The lengths of the ditches per municipality were multiplied with this average ditch width in order to get the m^2 water surface per municipality. The m^2 water surface was divided by the surface of the municipality (km^2), resulting in the m^2 water surface per km^2 per municipality.

The m^2 water surface first has been shown on a shape file, which contains the m^2 water surface per km^2 per municipality. After this the shape file has been converted into a raster file in which every raster has its own value. The raster cells will get the value of the m^2 water surface per km^2 per municipality.

Chloride concentration

Data on chloride concentration has been gathered for the years 1934, 1992 and 2003. It has been gathered in three different ways. The chloride concentration for the year 1934 was taken from the published report of Van der Torren. In his report, Van der Torren uses the method of Goethart and Jongmans[2] *(quarter boxes)* to indicate the location of the measurements.

Goethart and Jongmans used these quarter boxes to indicate the locations of plant species in the Netherlands in 1902. A map with the quarter boxes is needed to detect the coordinates of the sample locations (of Van der Torren) as well it is needed to put the chloride concentrations in a database connected to the sample locations. To do so a raster of the quarter boxes has been made by *Frans Rip* of the Geodesk of the University of Wageningen. Mr. Rip had already numbered the staff maps and the hour boxes, while the quarter boxes still had to be numbered. This raster can be laid over the map of Noord-Holland. The sample locations have been put into a point theme connected to a shape file of the province Noord-Holland. This shape file of the province Noord-Holland has the RD-coordination system (Dutch coordinate system). The raster of the quarter boxes have been laid over this shape file in order to locate the coordinates of the sample points as indicated in the report of Van der Torren.

Since Van der Torren took more samples on most of the sample points on different dates, the averages of the samples have been used for the database of the point theme. After finishing the shape file, the vector data has been converted into raster data in order to use it for the model.

For the years 1992 and 2003 shape files with the locations of the sample points are included with the chloride data. The data and the shape files are different for both years, but the method of processing data to be applied in the model is the same for both years. The chloride data only had to be filled-in in the attribute table of the shape file. The data was connected to the sample points at which it was taken. Some of the chloride data of some of the sample points was taken at more than one date. From these sample points the average chloride concentration is taken. The shape file finally was converted into raster.

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[2] For the method sixty-two (staff) maps, covering each a part of the Netherlands, were divided into six horizontal lines of eight boxes. Each box has a surface of 21 km^2 (5 * 4,2 kilometers). These boxes are named; *hour boxes,* because they are approximately one hour walking in as well North - South (4,2 km) as East – West direction (5 km). The hour boxes are dived into 16 boxes (4 * 4) and these boxes are so called; *quarter boxes*.

Host animals
The host animals have to be measured in number of animals per km^2 per municipality.
This state value will be incorporated into the model; the user can put in the desired data for this state variable.

Animal sheds/ stables
This state variable has to be measured in number of sheds/ stables per km^2 per municipality.
This state value will be incorporated into the model, but no data is yet available. The user can fill in the desired data for this state variable.

Rainfall intensity
The rainfall data for the years March until September derived from the website of the KNMI is: mm rainfall per day. For the model the rainfall intensity is needed in mm/day.
If the rainfall intensity exceeds 20 mm/day, a lot of the larvae will be flushed away. For every month is considered if a rainfall intensity of higher than 20 mm/day did appeare, if so X (filled in by the user) percent of larvae will be flushed away. The user is able to put in another dying factor in percent caused by other circumstances.
The rainfall intensity is assumed to be equal for the whole research area.

Temperature
The monthly averages temperatures of the months March till September have been derived from the KNMI website. The data is given in 0,1 ºC so the given temperature has to be multiplied with 0,1 to get the temperatures in ºC.
The aquatic and air temperature is assumed to be equal for the whole research area.

Relative humidity
The relative humidity is assumed to be optimum for the malaria mosquitoes all the time in the research area. A relative humidity of 60 % is used to represent the relative humidity into the whole research area. After doing some more research at the relative humidity, the user can change this value into the model.

Population density
The population density has been calculated as the *amount of inhabitants per* km^2 *per municipality* for the years 1934, 1992 and 2003. To do so the number of people per municipality and the municipality boundaries are needed. Since no data on the exact borders of 1934 and 1992 are available, the amount of inhabitants per municipality for the years 1934 and 1992 have been taken with the municipality borders of 2003.
Therefore data of the years 1934 and 1992 partly had to be processed. Most of the municipality borders were the same for the year 1992 and 2003, but some of them have changed in size, due to consolidation and municipality border change. Since 1934 a lot of changes took place, most of them due to consolidation.
The change of municipality borders has been considered insignificant so consolidation has only been taken in account.
To derive the amount of inhabitants of consolidated municipalities (municipality borders 2003) the amount of inhabitants of the components (municipality data of the years 1934 and 1992) of the consolidated municipalities had to be added. The amount of inhabitants per municipality can be filled in into a database file. The model will convert the data to the municipality borders and divide it with the municipality area to derive the amount of inhabitants per km^2.

4.5 Accuracy of the data

Not all input data for the model could be obtained easily and in the right format, therefore some data is more reliable that the other. Vegetation data for the years 1992 and 2003 and chloride data for the year 2003 has been gathered from the website of the HHNK. The chloride- and vegetation data was only available for the area above the IJ-canal. Due to this lack of information, the area below the IJ-canal had to be excluded from the research since no objective result could be obtained. For the year 1934, vegetation- and chloride data is available for the whole area. The chloride- and vegetation data has been saved into a point shapefile. Because of this, only vegetation types and chloride concentrations at point locations are known, this makes it difficult to translate them to a municipality.

The m^2 water surface per municipality is determined by a visual interpretation; first the m^2 of water surface of all ditches smaller than 3 meter wide has been determined for the year 2003 from the topological map (top50). It is not clear whether all ditches are shown on this map or not, so it is a rough estimation. There was assumed that the m2 of water surface in the year 1992 was equal to the m2 of water surface in 2003. For the year 1934 the historical map has been used to estimate the water surface per municipality, the water surface of the year 2003 has been compared to the water surface on the historical map. From this map the decline of the water surface between the year 1934 and the year 2003 has been estimated. The historical map dates back from the year 1900 so it might not be fully accurate for the year 1934. Therefore it has been used to give an impression of the water surface per municipality in the year 1934.

For the years 1992 and 2003 no data is available about the amount of animal sheds/ stables and the number of host animals per province. For the year 1934 there is assumed that the number of animal sheds/ stables and the number of host animals are sufficiently present for the existence of malaria mosquitoes.

Climate data; relative humidity, temperature and rainfall, has been gathered from the KNMI website. The data was taken from the KNMI station in the Bilt. Although this meteorological station is spaced at some distance from the research area, the data from this station is more complete and reliable. Because the spatial variation of weather in The Netherlands is not significant, there is assumed that this data is reliable and good to use.

The population density per municipality for the years 1992 and 2003 has been taken from the CBS website, the CBS being the Dutch statistical agency. The data provide by the CBS is assumed to be reliable and accurate. The population density per municipality for the year 1934 was provided by the archive of Noord-Holland (*Noord-Hollands archief*). Due to changes of the municipality in time, the data of the year 1934 had to be converted to recent municipality borders (see paragraph 4.4, subheading: population density). Due to this conversion the data probably became less accurate, the population of some municipalities increased while the population of other municipalities has declined.

4.6 Calibration data

To calibrate the model historical data, data of the province Noord-Holland as well as data on malaria, is needed. Data of the year 1934 has been used for the calibration of the model. Chloride data, vegetation data, demographic data and climatic data has already been mentioned in the previous paragraphs for the year 1934. The main source of data was the research conducted by *Van der Torren* in 1934. Chloride data and vegetation data was taken from that report, also the number of mosquitoes per m^2 of water surface was taken from this report. Locations in the whole Netherlands have been sampled by Van der Torren, including locations in the province Noord-Holland. The larvae densities of mosquitoes were determined by means of the *"soup ladle method"*. By means of a soup ladle, samples from open waters (dips) are taken, the samples are inspected on the presence of mosquito larvae. Information about the number of mosquitoes per dip and the amount of *An. atroparvus* and *An. messeae* mosquitoes per total dips per location, were determined. To determine the number of An. atroparvus and An. messeae per dip, the number of dips per location had to be determined. In the methodology of the report of Van der Torren there is mentioned that at least 30 larvae had to be examined per location. If more than 30 larvae were found at the first dip and the density of larvae remained approximately the same, five dips were taken. If the number of larvae decreased after this first dip, at least 10 dips were taken.

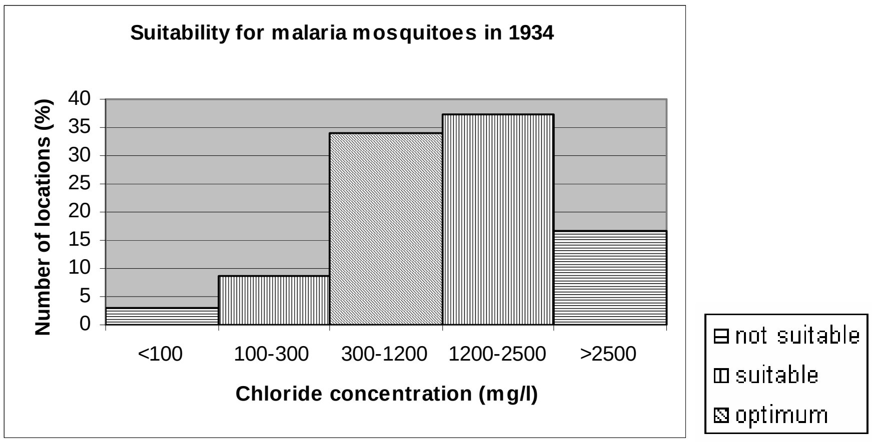
A location was determined to be not suitable for mosquitoes if during 30 dips, no or almost no larvae were found. Taking this methodology in consideration an estimation of the number of dips per location was made. The average number of larvae per dip was derived from the report and from this the amount of dips has been defined. Assumed was that if the average number of larvae per dip was ranging from zero until three larvae per dip, 30 dips were taken. If the average number of larvae per dip was ranging from more than three until 30 larvae per dip, ten dips were taken. Five dips were taken if the average number of larvae was bigger than 30 larvae per dip. Using this classification the number of *An. atroparvus* and *An. messeae* larvae was calculated. For example if a number of 20 *An. atroparvus* larvae was captured at one location in 10 dips, the average number of larvae per dip will be 20/10 = 2 larvae per dip. To determine the number of larvae per m^2 water surface, the water surface sampled per dip was calculated to be 135 cm^2 (*Takken et. al., Royal Swedish Academy of Science, 2002*).

Morbidity data is needed to calibrate the model. In the report of the malaria committee of Noord-Holland (*Commissie voor de malaria-bestrijding Noord-Holland, 1935*) monthly morbidity data is given for eleven districts in the province Noord-Holland. The results of the model can be compared and be calibrated to this. *(See appendix 2 data used and see appendix 3 for the nr of mosquitoes calculated).*

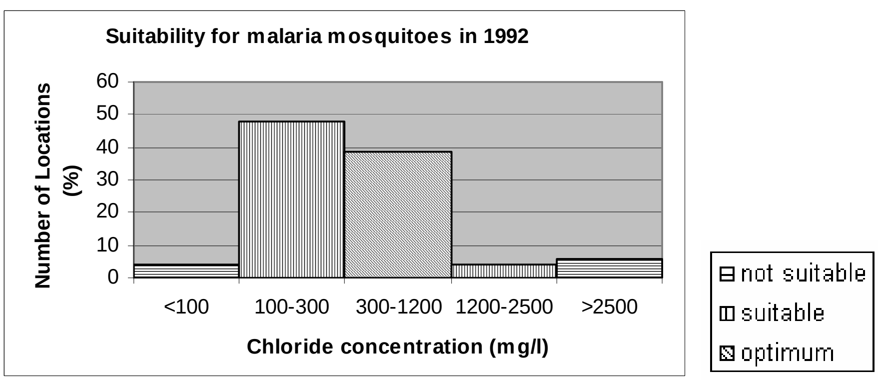
4.7 Data comparison

In this paragraph some of the input data for the model is compared for the three different years. Chloride concentration (mg/l), aquatic temperature (ºC/month) and average rainfall (mm/month) are compared for years 1934, 1992 and 2003. The rainfall intensity versus temperature and the population versus water surface are compared for the year 2003.

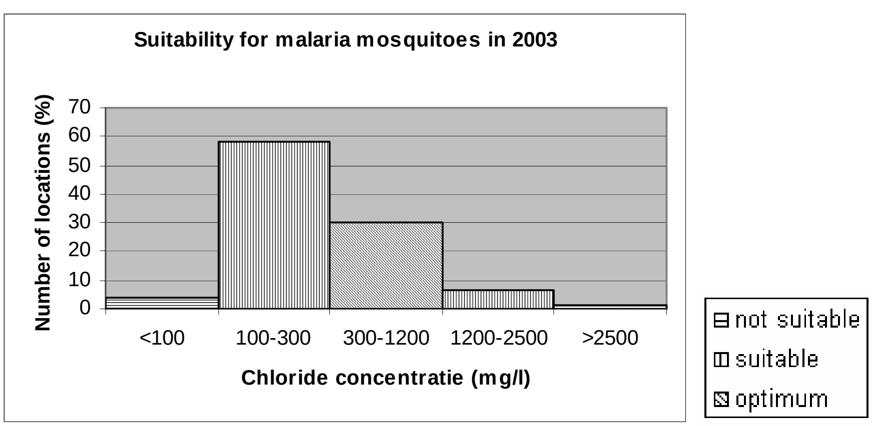
Chloride concentration



Graph 4.1: suitability for malaria mosquitoes in 1934

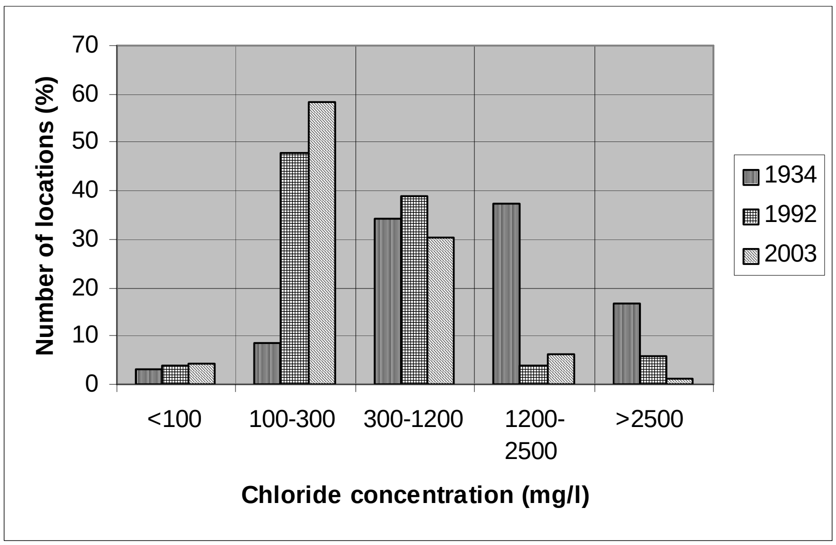


Graph 4.2: Suitability for malaria mosquitoes in 1992



Graph 4.3: suitability for malaria mosquitoes in 2003

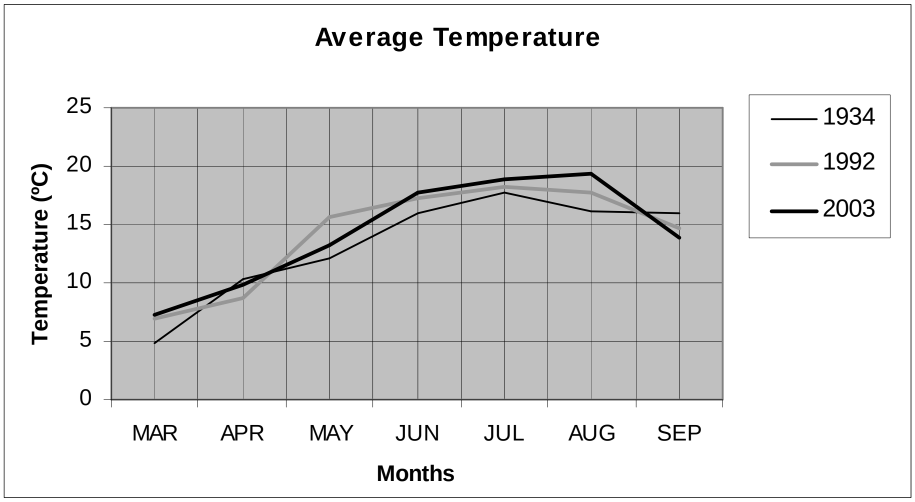
The chloride data for the year 1934 is measured by Van der Torren and mentioned in tables in his report. The chloride data for the years 1992 and 2003 are measured by the HHNK. So some differences in measuring method have to be taken in account when comparing the data. Assuming the data is right, the years 1992 and 2003 have a lot in common. Most of the sampling points have a chloride concentration in the range from 100 mg/l till 300 mg/l. Remarkable is the fact that many sample locations appeared to have chloride concentration that ranges from 300 till 1200 mg/l, which is the optimum concentration for malaria mosquitoes.
The chloride data of the year 1934 differs from the ones of the years 1992 and 2003. In this year most of the sample points have a chloride concentration ranging from 1200-2500 mg/l, this represents a suitable chloride concentration for the malaria mosquito just like the concentrations within the range from 100 till 300 mg/l. In the year 1934 approximately 35% of the sample points lay in between the range from 300 till 1200 mg/l which is almost the same as for the years 1992 and 2003.



Graph 4.4: Chloride concentrations for the years 1934, 1992 and 2003

In table 4.4 above the three different years are shown in one graph. The graph clearly shows that the year 1934 deviates from the other years. Especially for the range from 100 till 300 mg/l and the range from 1200 till 2500. For the other ranges the difference between the three different years are not that big.
It can be concluded that most of the sampled points lay in the suitable or optimum range of the chloride concentration for malaria mosquitoes. Before the chloride concentration was assumed to be important on the existence of malaria mosquitoes, because there was assumed that malaria mosquitoes preferred brackish water. Later on this assumption was not proven.

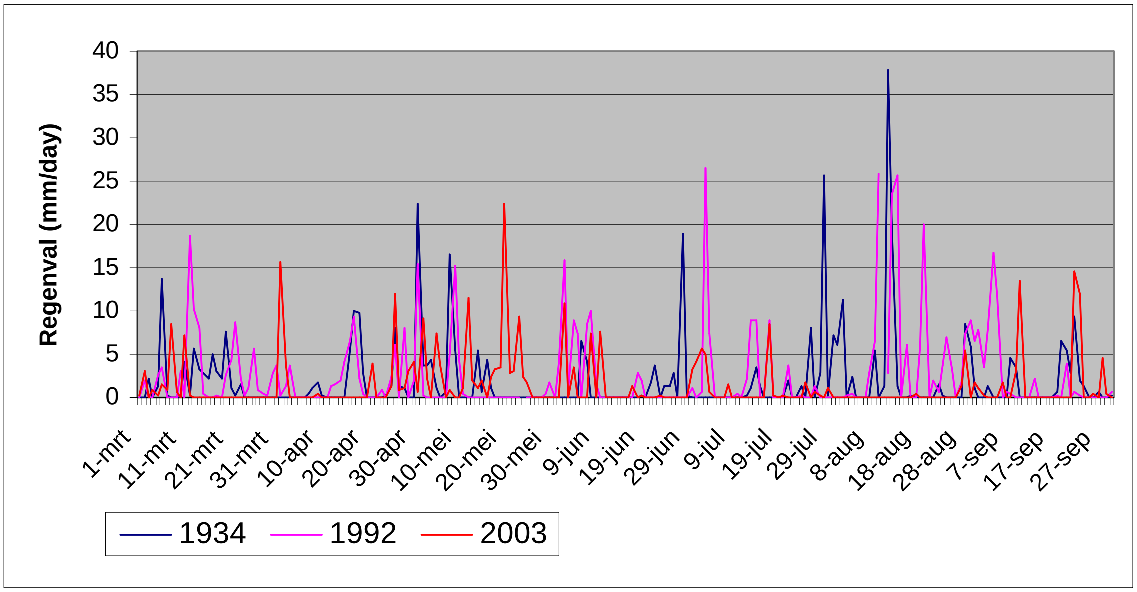
Temperature



Graph 4.5: Average temperatures for the years 1934, 1992 and 2003.

The temperature is of importance on the development of the *Plasmodium vivax*. With temperatures lower than 15 (ºC) and higher than 28 (ºC) the *Plasmodium vivax* is not able to develop inside the malaria mosquito. (Gilles & Warrel, 1993).
Looking at graph 4.5; you can see that the temperature in the months June till September for the year 1934 is right for *P. vivax* to develop. For the year 1992 the temperature in the months May till August is high enough for the *P. vivax* to develop. The year 2003 has only three months (June till August) in which the temperature is high enough for *P. vivax* to develop. The temperature is also important for the development of malaria larvae. The minimum water temperature at which malaria mosquitoes develop is 10 (ºC). The development time of the larvae is 6 weeks or longer at 10 (ºC). At average water temperature of 18 (ºC) the development time of larvae is 2,5 weeks at temperatures of 25 (ºC) the development time increases till 7 days *(Takken et al., May 2002).* In one year there are 3 till 4 generations depending on the temperature.
There is assumed that the aquatic temperature is 2,5°C higher than the air temperature. This is assumed according to a comparable research in Zuid-Holland where is stated; on average, at the surface, the temperature of the water was 2,5°C higher than that of the ambient air *(Takken et al., May 2002.).* From the month May till September the temperatures are alright for the mosquitoes to develop. Concluding it can be stated that the temperatures in the months June until September are high enough for the development of mosquito larvae and for the development of the *Plasmodium vivax* in the mosquito. Looking at the temperature it can be stated that malaria possibly can exist in the months June until August.

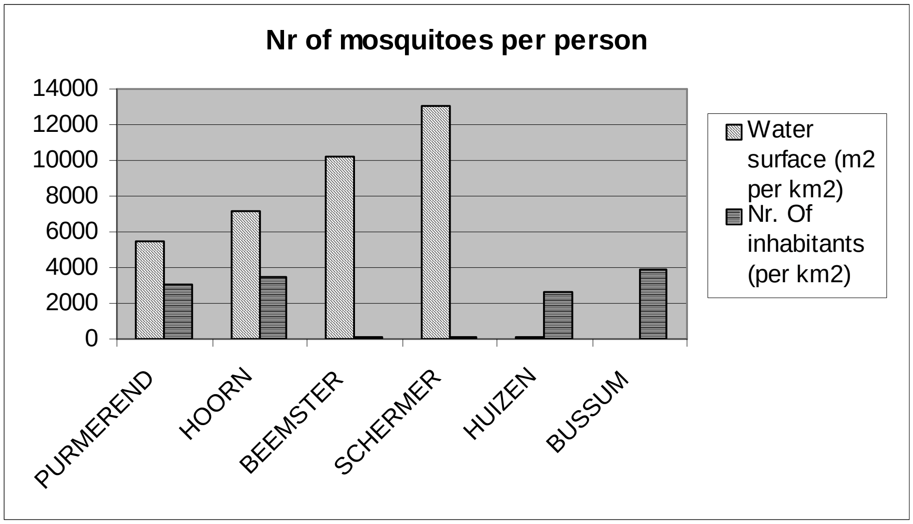
Rainfall



Graph 4.6: rainfall per day for the months March until September

Most of the rain fell in the year 1992 and the least rain fell in the year 2003. The month August is for the years 1934 and the year 1992 the wettest month. For the year 2003 the month May is the wettest month. An amount of rainfall of bigger than 20 mm/day will cause flushing away of many larvae. In the year 1934 the amount of rainfall is on three days higher than 20 mm/day. In the year 1992 there are four days right after each other where the amount of rainfall exceeds 20 mm/day, in this case there can be assumed that almost every larvae will be flushed away. In the year 2003 there is one day where the amount of rainfall exceeds the limit of 20 mm/day, rainfall damage on the larvae development will be very low in this year.
The female mosquitoes will lay new eggs just after the rainfall and after a period of three weeks new mosquitoes will be developed. However the died mosquitoes will cause a gap in their generation. There are three till four generations of larvae per year *(Swellengrebel & de Buck 1938)*.

Population versus water surface



Graph 4.7: Water surface and inhabitants per km2 per municipality for 2003

In graph 4.7 the number of people and the m^2 water surface per km^2 per municipality are researched. The water surface per municipality (m^2 water surface per km^2 per municipality) is important for the existence of malaria mosquitoes. Assumed is; the more m^2 water surface per municipality, the more larvae will exist. In the model the user can put in the number of mosquitoes per m^2 per km^2 per municipality. When comparing the m^2 water surface per km^2 per municipality with the number of people per km^2 per municipality, the number of mosquitoes per person can be calculated. The municipalities Purmerend and Hoorn are densely populated municipalities with a large water surface. There are a moderate number of mosquitoes per person, but because of the high population density transmission of malaria should be possible. The municipalities Beemster and Schermer have a few inhabitants and a big water surface because the inhabitants probably live far from each other, the chance malaria will be transmitted is very low. In the case of the municipalities Huizen and Bussum a very small water surface till no water surface is present in the municipality. This means almost no larvae can develop in these municipalities; the chance on transmission of malaria is very low in this case. There can be concluded that municipalities like Purmerend and Hoorn, which are densely populated and have a large water surface, are the most suitable municipalities for malaria transmission.

State variables for the three different years

Parameter	**1934**	**1992**	**2003**
Km² water surface per municipality	-	-	Visual interpretation topological map (1:50000). Ditches smaller than 3 meters. Meter water surface per municipality * 2 meter.
Aquatic Vegetation	Locations where the plant species exist in 1934 (Van der Torren). Plant species; *Enteromorpha ssp., Elodea canadensis and Phragmites australis*	Locations where the plant species exist for the years 1990, 1991, 1992, 1993 and 1994 (HHNK). Plant species; *Enteromorpha ssp., Elodea canadensis, Phragmites australis and Elodea nuttallii*	Locations where the plant species exist for the years 1999, 2000, 2001, 2002 and 2003 (HHNK). Plant species; *Enteromorpha ssp., Elodea canadensis, Phragmites australis and Elodea nuttallii*
Chloride concentration	Chloride concentration in mg/l measured in 1934 by Van der Torren.	Chloride concentration in mg/l measured in 1992 by the province Noord-Holland	Chloride concentration in mg/l measured in 2003 by the province Noord-Holland
Host animals	-	-	-
Animal sheds/stables	-	-	-
Rainfall intensity	Rainfall higher than 20 mm/day (KNMI)	Rainfall higher than 20 mm/day (KNMI)	Rainfall higher than 20 mm/day (KNMI)
Aquatic temperature	Average maximum and minimum air temperature in ºC for the months March until September (KNMI) + 2,5 ºC	Average maximum and minimum air temperature in ºC for the months March until September (KNMI) + 2,5 ºC	Average maximum and minimum air temperature in ºC for the months March until September (KNMI) + 2,5 ºC
Relative humidity	60% (assumption)	60% (assumption)	60% (assumption)
Population density	Amount of people 1934 per km² per municipality Municipality border 2003	Amount of people 1992 per km² per municipality Municipality border 2003	Amount of people 2003 per km² per municipality Municipality border 2003

Table 4.8: Data comparison for the years; 1934, 1992 and 2003

Other input parameters
The other input data, which is not compared are: Aquatic vegetation, km^2 water surface, host animals, animal sheds/ stables and the relative humidity.

- The data about the aquatic vegetation was very different for the three years as well as for the different locations. Due to differences in measurement techniques and locations, a comparison between the aquatic vegetation for the three different years is not revealing.
- The km^2 of water surface is only known for the year 2003. So comparison with other years is not possible.
- No data about host animals and animal sheds/ stables is available, therefore the users are enabled to fill-in that data in the model themselves.
- The relative humidity in the Netherlands is assumed to be suitable for the malaria mosquitoes. A relative humidity of 60% has been taken for every year and for the whole research area.

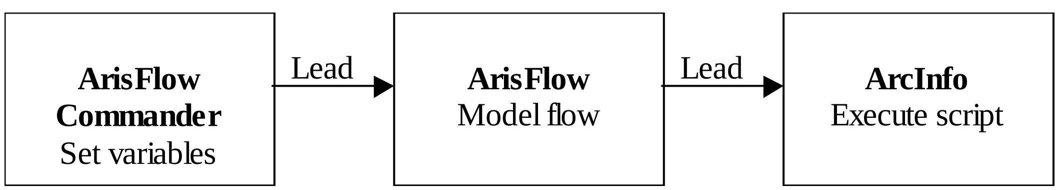
5 The Application

5.1 Introduction

In Chapter three and four the model structure and the input data have been described. In this chapter the construction of the simulation model and the GIS tools used to build the model, will be mentioned. The working of the simulation model and the way to use it will be explained. In paragraph 5.2 the GIS tools, which are used to build and run the simulation model, will be mentioned. Paragraph 5.3 explains the simulation model and how to fill in the data and how to run the model.

5.2 Application building

The application is build with use of the GIS programs ArisFlow and ArcInfo. Both programs are products of the company ESRI (Environmental Systems Research Institute). In ArisFlow it is possible to process a flow schema, and in ArcInfo it is possible to process spatial data. A connection between the two can be made. ArcInfo can run the script lead by ArisFlow. The script in ArisFlow is written in the programming language: Arc Macro Language (AML) and will be executed in ArcInfo. To make it easier for the user to give in the input parameters (state variables), the model variables and the input grids, ArisFlow Commander is used. ArisFlow Commander is a program communicating with ArisFlow, it starts ArisFlow and sends commands. To execute ArisFlow Commander, a simple script file is needed. The script file can be made in a simple text program like Notepad. This script file set the predefined values for variables into ArisFlow. The values easily can be changed by the user in the script file, it is also easy to run different scenarios with one script. ArisFlow Commander sends DDE (Dynamic Data Exchange) commands to run ArisFlow.



5.3 The application manual

As mentioned in the previous paragraph, the application is build in ArisFlow. In figure 5.1 a part of the model is shown. The gray boxes are the input grids or input tables and the white boxes are the output grids or output tables. The dots in-between of the input and output grids/ tables are the actions that contain the script, which will be executed by ArcInfo. (*See appendix 4 for the whole ArisFlow model*).

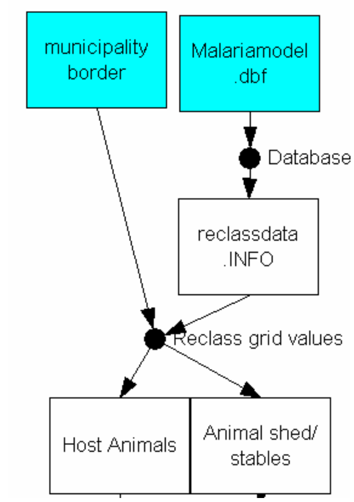


figure 5.1: Part of the simulation model.

The model consists of seven input grids, one input database file and a number of variables, which can be put in the ArisFlow Commander script. ArisFlow Commander is executed by a simple script that is made in Notepad. The ArisFlow script consists of four sections:

1. Commentary
Short description of the contents and operation of the script.

2. Variables
Declaration of the variables. All variables are mentioned here.

3. Server Script
Connects the declared variables to the defined variables in ArisFlow.

4. Output
This is the part that has to be filled in by the user. This section assigns values to the variables defined in ArisFlow.

Only the section 4 *(Output)* has to be filled in by the user. The rest has to remain the same, except when changes are made to the model. The user can change the values of the variables in the section output and can also run different scenarios with this section see figure 5.2. If the values of the variables are changed by the user, the script can be saved in notepad (with an .acf extension) and be executed with ArisFlow commander (see annex 5 for the script used in the model).

In order to run the model, first the following steps have to be made. The right Grid names for; the municipality borders, province borders, the four vegetation types and the grid with chloride concentrations are to be filled-in in the ArisFlow Commander script.
In the model database file; the m^2 of water surface per municipality, the number host animals, the number of animal sheds/ stables and the population per municipality have to be filled in (in Excel). A Selection of the data has to be made and the database can be saved with the database extension.
In ArisFlow Commander the right database name and the remainder of the variables have to be filled-in and the ArisFlow Commander script can also be saved.

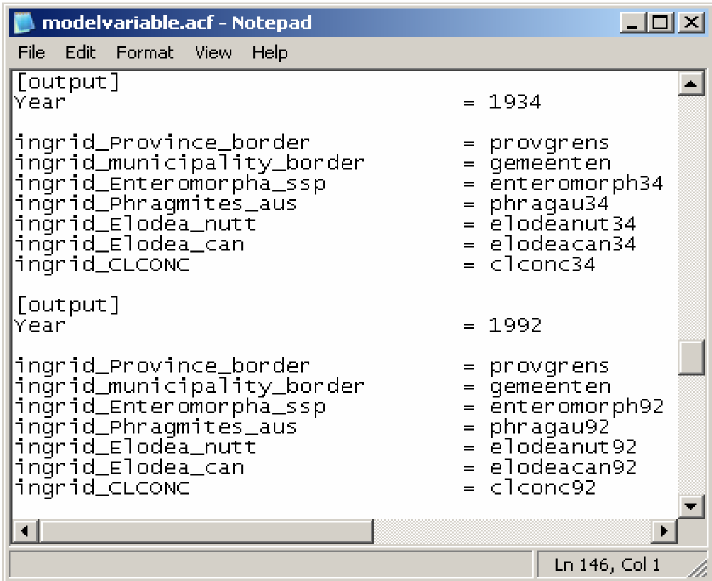


Figure 5.2: Two scenarios in a ArisFlow Commander script.
(the user can change the values of the variables).

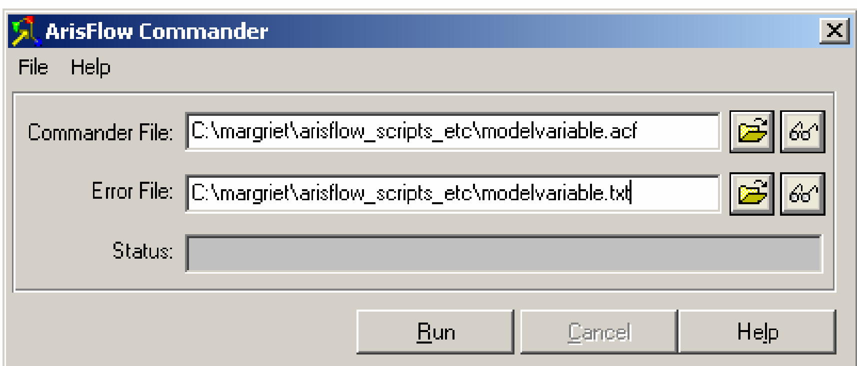


Figure 5.3: ArisFlow Commander.

To execute the model, first the commander file has to be selected. Than the text file, which will note down the errors that can possibly occur, has to be defined. When this is done the model can be processed. Push the run button and the model will be executed in ArisFlow, containing the variables set in the ArisFlow commander script. The output will appear in maps into ArcInfo and as database files into Excell.

5.4 Application probabilities

The simulation model is made for the Dutch province Noord-Holland but with some little changes it might also be applicable for other provinces in The Netherlands. The input grids and the input database files than have to be changed. It is important to use the same settings for the database file and the grids.
The variables, as mentioned in paragraph 5.2, can be changed in ArisFlow Commander. So it is rather easy to use it for other provinces in The Netherlands, however a basic knowledge of GIS is required to make the model appropriate for other provinces.

6 Model analysis

6.1 Introduction

To analyse the model the method described in the GMP handbook has been used. The following tests have been done: global analyses, sensitivity analysis, formal identification, calibration, uncertainty analysis and validation. The schematic representation of the model analysis is shown in figure 6.1.

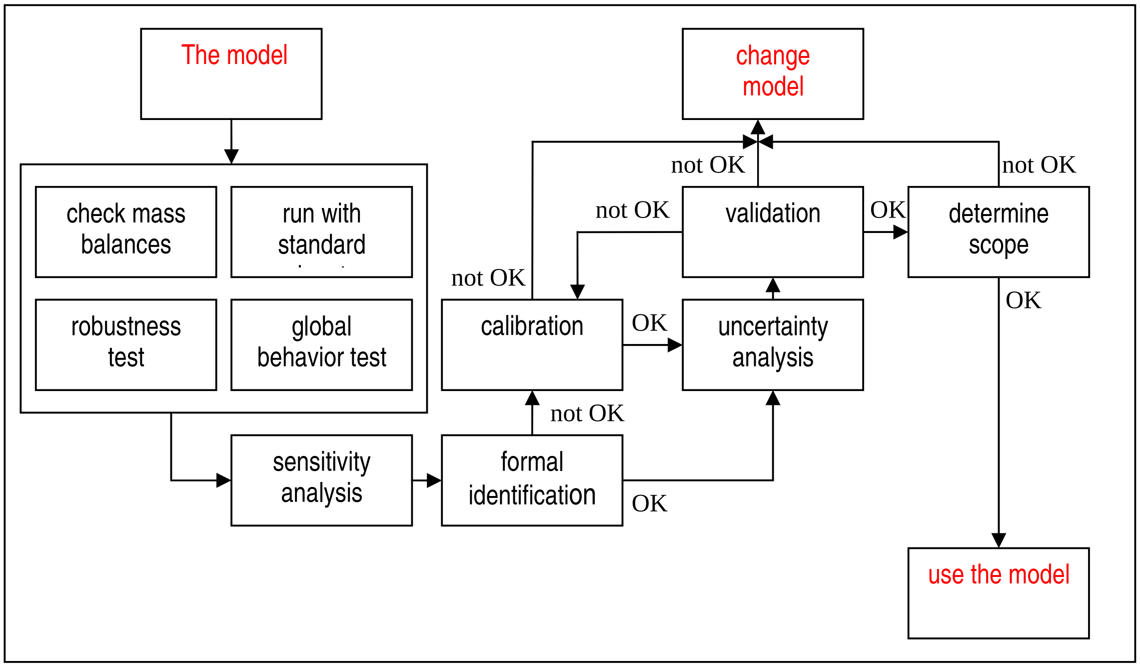


Figure 6.1: Schematic representation of the model analysis. (According to the GMP handbook).

To do the model analysis, the formula used in the model will be elaborated.

$$VC = \frac{(ma^2 p^n)}{(-\ln p)} \qquad \textit{(Garrett-Jones, 1964)} \qquad [1]$$

The formula parts are represented by the state variables and by the other variables of the model. To determine the main influencing variables of the model, there will be focussed on the variables that are filled-in by the user. The variables of the model will be elaborated individually.

Variable m

Variable m is the number of female mosquitoes per person. Variable m is determined by the number of mosquitoes per municipality divided by the number of inhabitants per municipality. The number of mosquitoes per municipality is determined by the number of mosquitoes per m^2 of water surface multiplied by the m^2 of water surface per km^2 per municipality. The number of mosquitoes per municipality is also influenced by rainfall. As a result of heavily rainfall mosquito larvae will be flushed away.
So the variables, which determine *variable m* are: m^2 of water surface per km^2 per municipality, number of mosquitoes per m^2 of water surface, the number of inhabitants per municipality and rainfall intensity. Data for the number of inhabitants per municipality is gathered from the CBS-website (*statistical agency*) and can be considered as reliable data. Data for the m^2 of water surface per km^2 per municipality is estimated from maps and data for rainfall are gathered from

the KNMI website (meteorological station). The variation variable influencing the value of *variable m* is the number of mosquitoes per m^2 of water surface. This value can be changed by the user.

Variable a
Variable a is the daily biting rate of female mosquitoes on human. It is determined by the Human Blood Index * the feeding frequency. The Human Blood Index for Anopheles atroparvus mosquitoes and Anopheles messeae mosquitoes is determined to be 0,05. The only variation variable influencing the value of *variable a* is the feeding frequency.

Variable p
Variable p is the daily mosquito survival rate and is determined by the weights of the four state variables: relative humidity, average temperature, animal sheds/ stables and number of host animals. Due to a lack of data the daily mosquito survival rate is set on 0,85. This should be variable and the weights of the mentioned state variables should influence the value of *variable p*.

Variable n
Variable n is the extrinsic incubation period. *Variable n* is determined by the average temperature. The average temperature influences the value of *variable n.* It is taken from the KNMI website.

There can be concluded that the variation variables which have the most influence on the output of the model are: the number of mosquitoes per m^2 water surface, the feeding frequency and the daily mosquito survival rate.
Therefore these variables will be used to analyse the model.

6.2 Global analyses

The global analyses contains three tests:

1. run with standard input
2. global behaviour test
3. the robustness test

When running the model with the standard data (data for the year 2003) the model runs fine. When changing the input variables of the model, the output of the model changes. The main variables which can be changed are: the number of mosquitoes per m^2 water surface, the feeding frequency and the daily mosquito survival rate. When changing these main variables an output can be expected. In table 6.1 the main variables are mentioned with a globally expected output and the real model output.

Variable	**Action**	**Expected behaviour**	**Real behaviour**
Nr. of mosquitoes per m^2 water surface	Increase	Output will increase	Output will increase
Feeding frequency	Increase	Output will increase	Output will increase
Daily mosquito survival rate	Increase	Output will increase	Output will increase

Table 6.1: Global behaviour of the model.

When looking at table 6.1 the global behaviour test was successful the behaviour answered to expectations.
To do the robustness test the same variables have been used as for the global behaviour test. The model was tested on its robustness by putting in very high and very low values for the variables see table 6.2 for the results of the robustness test.

Variable	High value	Output	Low value	Output
Nr. of mosquitoes per m^2 water surface	10^*e^{30}	Output = 0 Unreal output	< 0	Unreal output
Feeding frequency	10^*e^{30}	No data; model stocks	< 0	Unreal output
Daily mosquito survival rate	10^*e^{30}	Output = 0 Unreal output	< 0	No data; model stocks

Table 6.2: Robustness test.

As can be seen in table 6.2 the model does not function well when using extremely high or extremely low values. It has to be noticed that these extreme values are not realistic.

6.3 Sensitivity analysis

The definition of a sensitivity analysis is: investigate the relation between changing factors and model output (GMP Handbook).
For the sensitivity analysis the variables; number of mosquitoes per m^2 of water surface, the feeding frequency and the daily mosquito survival rate, have been used. From these different parameters will be individually checked how big their influence is on the model. Table 6.3 shows the ranges of the values.

Variable	Minimum value	Maximum value
Nr. of mosquitoes per m^2 water surface	0	1000 is taken as maximum nr of mosquitoes per m^2
Feeding frequency	0	1
Daily mosquito survival rate	0	1

Table 6.3: Variable ranges.

For the sensitivity analyse the variables mentioned above are changed individually. The other variables will be set for the situation of 2003. The default values for the other variables are shown in table 6.4 below.

Variable	2003
Chloride concentration (mg/l)	0 – 2500
Nr. Of mosquitoes/ m^2	500
Human blood index	0,05
Feeding-frequency	0,20
Daily mosquito survival rate	0,85

Table 6.4: Variable values used.

Number of malaria cases are calculated for the months March until September putting in the minimum and maximum values for the variables. In table 6.5 the results of this are shown.

	Malaria cases June		Malaria cases July		Malaria cases August	
Variable	*Min. value*	*Max. value*	*Min. value*	*Max. value*	*Min. value*	*Max. value*
Nr. of mosquitoes per m^2 water surface	0	0	0	0	0	0
Feeding frequency	0	4	0	4	0	6
Daily mosquito survival rate	0	113	0	113	0	115

Table 6.5: Malaria cases per month for maximum and minimum values of the variables.

Looking at table 6.5 the model is the most sensitive for changes in the variable *daily mosquito survival rate*. The second important variable is the feeding frequency. The model is least sensitive for changes in the number of mosquitoes per m^2 of water surface.

6.4 Calibration

During the calibration the output of the model is compared to the observations in the field. The smaller the deviation between the calculated model results and the field observations, the better the model. To calibrate the model, the data of the year 1934 has been used. The state variables used for calibration are; climatic data, habitat data and demographics data of the year 1934. The state variables are described in chapter four of this report and data is shown in appendix 2. Besides the state variables the model also contains a few other variables *(see appendix 5, the ArisFlow commander script for all variables).* The user of the model can easily change the variables.
The year 1934 has been used for the calibration of the model, in this year 1211 cases of malaria were reported *(Commissie voor de malaria bestrijding Noord-Holland, 1935*). From this 1211 cases 585 cases were malaria for sure. In 1934 not all doctors performed a blood test to determine the cause of the symptoms of illness, sometimes the diagnosis was untruly malaria. In the research there is assumed that all reported cases of malaria are truly malaria cases. The malaria committee of Noord-Holland divided the number of malaria cases into eleven districts. Figure 6.1 displays the malaria districts. From table 6.2 the number of malaria cases per month per district for the year 1934 can be read.

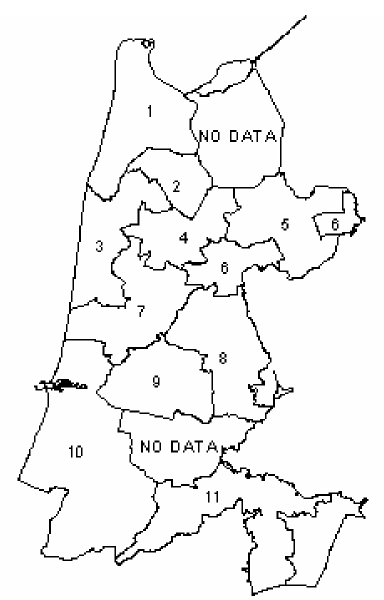


Figure 6.1: Districts malaria committee Noord-Holland

District	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	0	0	0	0	0	0	0	1	3	0	2	2	**8**
2	0	0	0	0	7	12	0	4	12	3	0	0	**38**
3	3	1	0	1	4	3	13	7	4	1	0	0	**37**
4	2	0	4	19	13	31	31	28	4	0	0	1	**133**
5	0	0	0	1	4	10	12	4	9	3	0	0	**43**
6	0	0	0	0	7	5	2	7	0	0	0	0	**15**
7	0	1	11	9	70	110	62	32	16	14	4	1	**330**
8	1	4	4	10	11	29	37	21	12	6	1	0	**136**
9	0	0	13	9	36	103	53	52	21	22	4	2	**315**
10	0	5	22	0	8	12	0	9	12	11	1	0	**80**
11	2	3	0	0	3	21	20	12	7	4	0	4	**76**
Total	8	14	54	49	157	336	230	177	100	64	12	10	**1211**

Table 6.6: Malaria cases per district per month in 1934 *(Commissie voor de malaria bestrijding Noord-Holland, 1935*).

In order to calibrate the model with the data of the year 1934; variables have to be filled-in in the ArisFlow Commander script (table 6.1 starting values for the variables). In the model database the; m^2 of water surface per municipality, the population density, animal sheds/ stables and the number of host animals for the year 1934 can be filled-in and saved. The grid names for the municipality borders, province border, vegetation types and chloride concentrations have to be filled-in in ArisFlow Commander. Running the model gives the vectorial capacity in the year 1934. It is assumed that this is equal to the number of malaria cases. The output has to be compared to the actual number of malaria cases in the year 1934 (table 6.2: Malaria cases per district per month in 1934). The output of the model are the malaria cases per month per municipality. The actual number of malaria cases in the year 1934 is given in the table as malaria cases per district per month. To obtain the output of the model in malaria cases per district per month, the results of the municipalities located in one district have to be summed up. In appendix 6 the municipalities for the year 2003 per malaria district are mentioned.

Calibration can be divided into three parts: choice of parameters to be optimised, calculation of the optimal values and analyses of the results of the optimisation.

6.4.1 Optimisation parameters

The parameters to be optimised in the model to get a good match of the output of the model with the actual situation 1934 will be the daily mosquito survival rate and the daily biting rate of female mosquito on human. The daily mosquito survival rate is chosen because the model is the most sensitive for changes of this variable. The second variable is the feeding frequency, this value is also of importance on changes in the model output.

6.4.2 Optimal values and results

The variables were changed manually in the model. By trial and error the best match was determined. As was mentioned in subparagraph 6.4.1, the feeding frequency and the daily mosquito survival rate have to be adapted in order to get the best match between the actual and the calculated situation. In Table 6.7 the default values for the model are mentioned.

Variable	**1934**
Chloride concentration (mg/l)	700 – 2500
Nr. Of mosquitoes/ m^2	Per province (appendix 3)
Human blood index	0,05
Feeding-frequency	0,20
Daily mosquito survival rate	0,85

Table 6.7: Default values of the model for the year 1934.

The values used for calibration are mentioned in tables 6.8.

Calibration	**Feeding frequency**	**Daily mosquito survival rate**
Cal 1.	0,20	0,85
Cal 2.	0,20	0,90
Cal 3.	0,20	0,80
Cal 4.	0,20	0,75
Cal 5.	0,30	0,80
Cal 6.	0,30	0,85
Cal 7.	0,30	0,82
Cal 8.	0,25	0,80
Cal 9.	0,25	0,81
Cal 10.	0,25	0,79
Cal 11.	0,35	0,80
Cal 12.	0,30	0,81
Cal 13.	0,30	0,79
Cal 14.	0,25	0,82

Table 6.8: Values used for calibration

The cumulative difference for the months March until September between the model output and the actual situation for every calibration is placed in table 6.9. The deviation of the cumulative difference as a percentage of the actual situation is placed in table 6.10.

	March	April	May	June	July	August	September	Total
Cal 1.	5	4	15	27	18	13	21	**103**
Cal 2.	5	4	15	100	24	25	109	**283**
Cal 3.	5	4	15	27	20	15	7	**93**
Cal 4.	5	4	15	30	21	16	9	**100**
Cal 5.	5	4	15	23	19	14	10	**90**
Cal 6.	5	4	15	53	17	12	55	**162**
Cal 7.	5	4	15	27	18	13	21	**103**
Cal 8.	5	4	15	25	20	15	7	**90**
Cal 9.	5	4	15	24	19	14	9	**90**
Cal 10.	5	4	15	26	20	15	6	**91**
Cal 11.	5	4	15	25	18	13	15	**95**
Cal 12.	5	4	15	24	18	13	14	**94**
Cal 13.	5	4	15	24	19	14	7	**90**
Cal 14.	5	4	15	24	18	14	13	**92**

Table 6.9: Average absolute cumulative difference per district per month.

	March	April	May	June	July	August	September
Cal 1.	100	100	100	90	87	79	227
Cal 2.	100	100	100	327	116	158	1202
Cal 3.	100	100	100	87	97	95	75
Cal 4.	100	100	100	98	100	100	94
Cal 5.	100	100	100	76	91	86	106
Cal 6.	100	100	100	173	83	75	608
Cal 7.	100	100	100	90	87	79	227
Cal 8.	100	100	100	81	94	91	79
Cal 9.	100	100	100	77	92	88	96
Cal 10.	100	100	100	84	96	93	71
Cal 11.	100	100	100	81	86	82	169
Cal 12.	100	100	100	79	86	83	155
Cal 13.	100	100	100	80	93	90	78
Cal 14.	100	100	100	77	88	84	140

Table 6.10: Deviation (in %) of the average measured.

As can be read in the tables the months March until May have the same outcome. This is cause by the fact that the model calculates no malaria cases for these months. When the average temperatures are to low (< 15°C) in the months March until May, development of Plasmodium vivax is assumed to be impossible. When looking at the calibration results in table 6.9 and table 6.10, there can be concluded that calibration 5 (feeding frequency = 0,30 and daily mosquito survival rate = 0,80) is the best match for the month June. For the months July and August calibration 6 is the best matching situation (feeding frequency of 0,30 and the daily mosquito survival rate = 0,85). For the month September, calibration 10 gives best matching output. Over all months, calibration 13 gives the best results. The deviation with output of the model and the actual situation is larger than 70 % and the months March until May do not give any output at all.
The model output is not acceptable yet. There are various ways of obtaining better results, some of them are mentioned below:

Choose other calibration variables, without a new sensitivity analysis.
Choose other calibration variables, after doing a new sensitivity analysis.
Go back and change the model.
Collection of more other or other field data.

There was chosen to run the model with the maximum temperatures per month in stead of running the model with average temperatures per month, to see whether a better match can be found for the calibration.
During calibration with the maximum temperature the feeding frequency and the daily mosquito survival rate had to be adjusted.

Calibration	**Feeding frequency**	**Daily mosquito survival rate**
Cal 1.	0,20	0,85
Cal 2.	0,22	0,79
Cal 3.	0,23	0,79
Cal 4.	0,20	0,79
Cal 5.	0,25	0,79
Cal 6.	0,20	0,80
Cal 7.	0,25	0,80

Table 6.11: Values used for calibration (with maximum temperature as input).

	March	**April**	**May**	**June**	**July**	**August**	**September**	**Total**
Cal 1.	5	23	12	40	17	11	38	**147**
Cal 2.	5	5	14	24	19	14	8	**90**
Cal 3.	5	5	14	24	19	14	9	**90**
Cal 4.	5	5	14	25	20	15	7	**90**
Cal 5.	5	6	14	23	19	13	11	**91**
Cal 6.	5	5	14	24	19	14	8	**90**
Cal 7.	5	7	14	24	18	13	15	**96**

Table 6.12: Average absolute cumulative difference per district per month.

	March	**April**	**May**	**June**	**July**	**August**	**September**
Cal 1.	100	518	83	132	83	68	420
Cal 2.	100	110	97	79	93	89	86
Cal 3.	100	116	97	77	92	88	96
Cal 4.	100	106	97	81	94	91	78
Cal 5.	100	127	93	76	89	84	121
Cal 6.	100	114	96	78	93	89	92
Cal 7.	100	100	100	81	94	91	79

Table 6.13: Deviation (in %) of the average measured.

From the tables the results can be read. Table 6.12 shows the total of the absolute cumulative difference between the model output per district per month and the actual situation per district per month. In this case calibration with the values of calibration number 2, 3, 4 and 6 give the best results. When calculating the deviation with the average number of measured malaria cases per month, calibration number 4 has the best match with the actual situation.

Looking at the results there can be concluded that comparing the total malaria cases per month with the actual malaria cases per month in 1934 gives better results than comparing the malaria cases per month per district with the actual malaria cases per month per district. So the malaria peaks are not situated in the right district. To combat this problem more data about the amount of water surface per municipality and the number of malaria mosquitoes per m^2 per km^2 should be gathered. The data used for the amount of water surface per municipality is estimated and therefore this data may contain inaccuracies. The data for the number of mosquitoes per m^2 per km^2 of water surface is estimated from the report of Van der Torren (1935). The data is derived from point data therefore it also may contain errors. To make the data more accurate and reliable, a good and detailed research should be conducted to determine the values for the input data for the year 1934.

The calibration results also can be compared for other cases. For example the model was set with the average temperatures and with the maximum temperatures. Using the maximum temperature as input the model also gave output for the Months April and May. Using the average temperature the model did not give output for the months March until May. This is due to the fact that there is assumed that below 15 °C no development of Plasmodium vivax is possible. To make the model more reliable, more detailed data should be used for the temperature. Development of Plasmodium vivax takes one and a half till three weeks at temperatures of at least 15 °C. Currently the average temperature for one month is used to predict the development time of Plasmodium vivax. In the actual situation the temperature can be lower than 15 °C for one week and higher than 15 °C for three weeks. The average temperature can still be lower than 15 °C. The model becomes more reliable when using weekly temperature data.

Based on this there can be concluded that the model is not ready for use yet. The model should be calibrated further. To do so some changes should be made to make the model more reliable and accurate.
Changes to be made are:
Collect more and accurate data for the m^2 of water surface per municipality in 1934.
Collect more and accurate data for the number of mosquitoes per m^2 of water surface in 1934.
Adjust the model to input to weekly average temperatures in stead of monthly average temperatures.

For now the best matching variable values will be used to calculated further with the model and values determined before by malaria experts (feeding frequency = 0,20 and the daily mosquito survival rate = 0,85). The calculations will be done using the average temperature as input as well as using the maximum temperature as input. The best matching variables values for calibration are:
When using the average temperature: Feeding frequency of 0,30 and a daily mosquito biting rate of 0,79.
When using the maximum temperature: Feeding frequency of 0,20 and a daily mosquito biting rate of 0,79.

7 Results

Runs were done for the years 1934 and 2003 with the results of; the best match of the calibration, the initial values determined by malaria experts and with a high value for the Human Blood Index. A run with a high value for the human blood index was done in order to obtain insight in the effect of high Human Blood Index on the output of the model. When for example recreation will intensify in areas with a lot of open waters, the Human Blood Index will most probably rise.
In table 7.1 the input values are mentioned for the different situations.

Initial values (malaria experts)	**1934**	**2003**
Human blood index	0,05	0,05
Feeding frequency	0,20	0,20
Daily mosquito survival rate	0,85	0,85
Nr. of mosquitoes per m^2 water	Maximum Per municipality (appendix 3).	Maximum = 300
Chloride concentration	700 – 2500	0 - 2500
Best matching calibration (avg. temp).		
Human blood index	0,05	0,05
Feeding frequency	0,30	0,30
Daily mosquito survival rate	0,79	0,79
Nr. of mosquitoes per m^2 water	Maximum per municipality (appendix 3).	Maximum = 300
Chloride concentration	700 – 2500	0 - 2500
Best matching calibration (max temp).		
Human blood index	0,05	0,05
Feeding frequency	0,20	0,20
Daily mosquito survival rate	0,79	0,79
Nr. of mosquitoes per m^2 water	Maximum Per municipality (appendix 3).	Maximum = 300
Chloride concentration	700 - 2500	0 - 2500
High value Human Blood Index.		
Human blood index	0,5	0,5
Feeding frequency	0,30	0,30
Daily mosquito survival rate	0,79	0,79
Nr. of mosquitoes per m^2 water	Maximum Per municipality (appendix 3).	Maximum = 300
Chloride concentration	700 - 2500	0 - 2500

Table 7.1: Input values for the model

In table 7.2 the output values of the model for the input values of table 7.1 are mentioned.

	March	April	May	June	July	August	September
1934							
Initial values (malaria experts*)*	0	0	0	306	78	78	306
Best matching calibration (avg temp)	0	0	0	126	24	24	126
Best matching calibration (max temp)	0	46	5	112	22	22	112
High value Human Blood Index	0	0	0	14778	4412	4412	14778
2003							
Initial values (malaria experts*)*	0	0	0	181	181	217	0
Best matching calibration (avg temp)	0	0	0	72	72	98	0
Best matching calibration (max temp)	0	24	1	63	63	188	0
High value Human Blood Index	0	0	0	8798	8798	11141	0

Table 7.2: Output of the model (total number of malaria cases per month).

According to the model malaria can occur in 2003 when there is assumed that there are 300 mosquitoes per m^2 of water surface and Plasmodium vivax is present.

Actual malaria cases June 1934 **Calculated malaria cases June 1934**

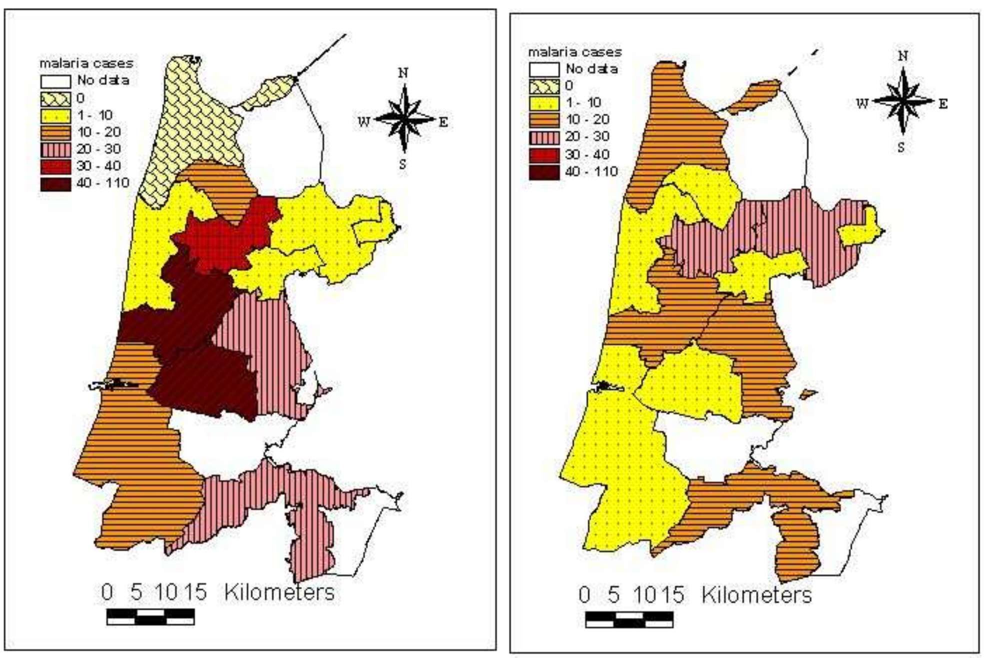


Figure 7.1: Actual malaria cases in June 1934 per district and calculated malaria cases in June 1934 per district (feeding frequency = 0,30 & daily mosquito survival rate = 0,79).

District	Actual June 1934	Calculated June 1934
1	0	11
2	12	7
3	3	4
4	31	21
5	10	26
6	5	5
7	110	16
8	29	11
9	103	3
10	12	9
11	21	11

Table 7.3: Malaria cases in June in the year 1934 (actual and calculated).

In figure 7.1 the peaks of malaria are displayed. Comparing the actual situation in the month June of the year 1934 with the calculated number of malaria cases at that moment, differences can be seen. In the actual situation the highest number of malaria cases are situated in the middle of Noord-Holland. Especially in the two districts containing the municipalities: Wormerland, Oostzaan, Schermer, Zaanstad and Castricum, a lot of malaria cases occurred. In the calculated situation these are the districts with moderate number of malaria cases, this deviation can be caused by errors in the input data. Looking at mosquito density data (Appendix 3) the mosquito density is rather low in these municipalities see figure 7.2. The data for the mosquito densities is derived from the report of Van der Torren (1934) and is based on point data. Therefore the data is can contain many errors.
The calculation of the malaria risk for district 6 gives the best match between the actual and the calculated situation, the model calculated 5 cases and in the actual situation this number was the same. Looking at the results that are displayed in figure 7.1 and table 7.3 there can be concluded that the overall outcome is not good enough. The deviation is to high but at some points there is resemblance. Especially in the districts 7 and 9 the deviation is very high.
To compare the outcome of the model for the year 2003 with the year 1934, the model was set with the input data of the best match of the calibration with the average temperature(see table 7.1). The results are displayed in figure 7.3. At the map of the year 2003, the Southern part of Noord-Holland has a outcome of zero. This because no data for as well vegetation as chloride concentration was found. To improve the model output data for this variables in the Southern part should be gathered. This is the same for the other maps of the year 2003.

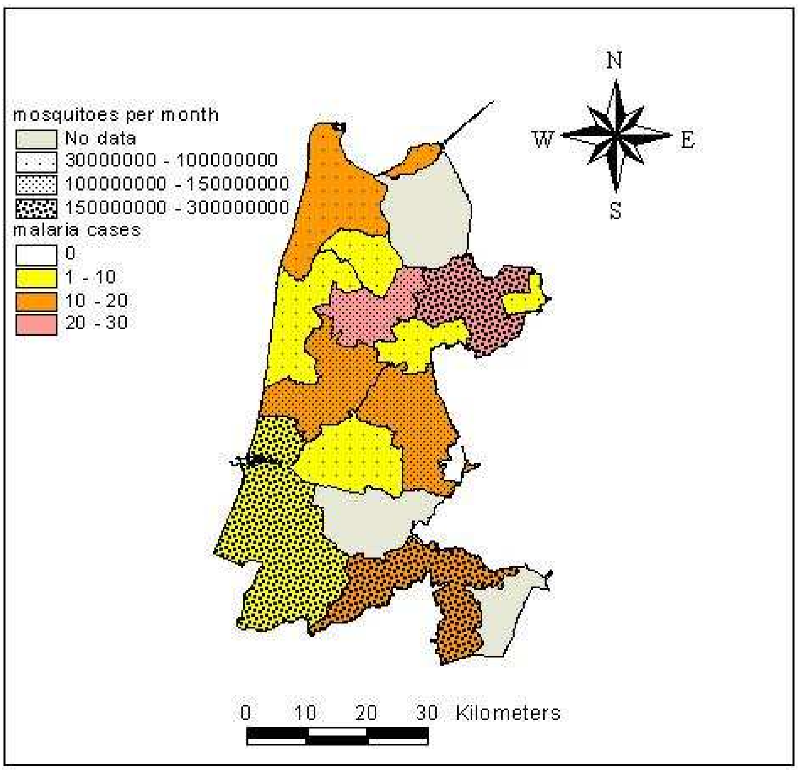


Figure 7.2: Number of mosquitoes per month per district for the month June and the year 1934.

From figure 7.2 some trends can be recognised when comparing the number of malaria cases per district with the number of mosquitoes per district. In areas with high mosquito densities, high number of malaria cases are expected. This is true for the districts in the North-East, but not for the district in the South-West. All other areas with low number of malaria cases have low mosquito densities.

Calculated malaria cases July 1934 **Calculated malaria cases July 2003**

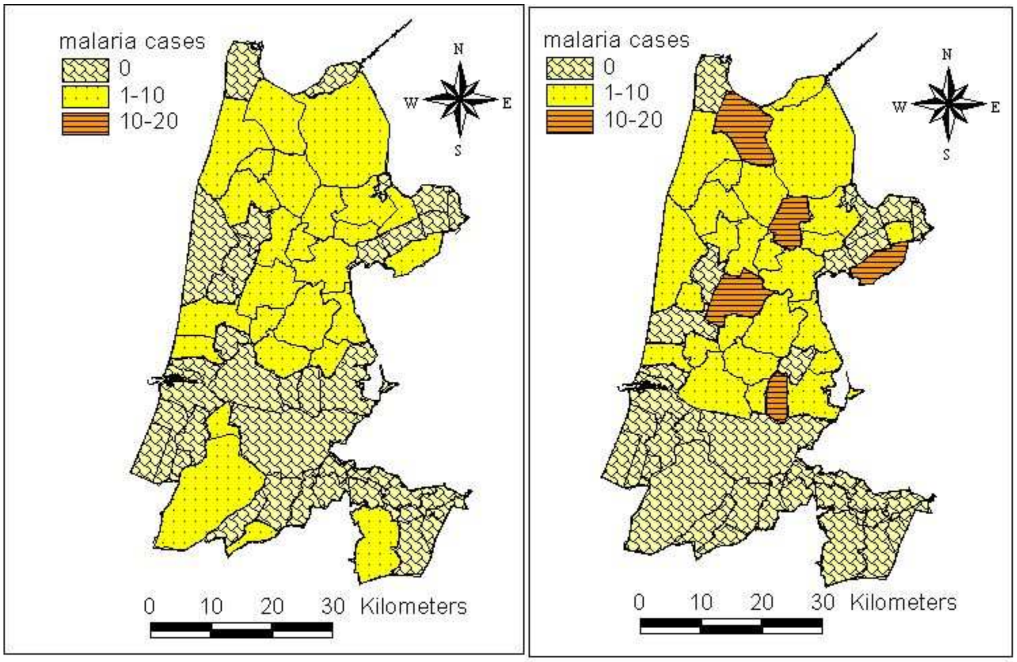
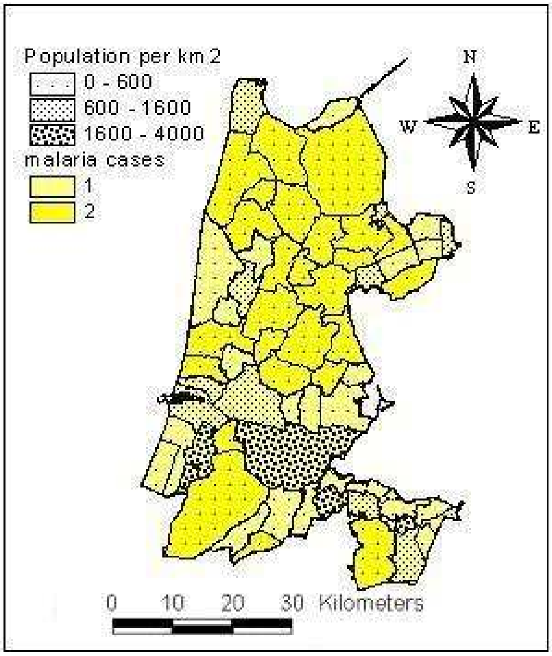


Figure 7.3: Calculated malaria cases of the month July for the years 1934 and 2003 (per municipality).

From the figure can be derived that the output of both maps show resemblance. The input for both years is the same, except from the input for the state variables: water surface per municipality, average temperature, number of mosquitoes per m^2 of water surface, rainfall and the population density. The overall number of malaria cases is highest for the year 2003. The input data type *temperature* did not show large differences for the two years, the water surface per municipality and the population density however showed a large difference for the two years. The year 1934 had the biggest m^2 of water surface. Since the number of mosquitoes per municipality is related to the amount of water surface, the number of mosquitoes per municipality is most probably the largest in the year 1934. The number of inhabitants in 2003 was higher compared to the number of inhabitants in 1934. Factor m of the model formula is determined by the number of mosquitoes per km^2 per municipality divided by the number of inhabitants per km^2 per municipality, therefore it is expected that the year 1934 has the highest amount of malaria cases. In the month July in the year 1934 a case of heavily rainfall occurred resulting in a decrease of malaria larvae. That is why the year 2003 shows the most cases of malaria for the month July.

Figure 7.3 shows the relation between population density and malaria risk.

Calculated malaria cases 1934 & Population



Calculated malaria cases 2003 & Population

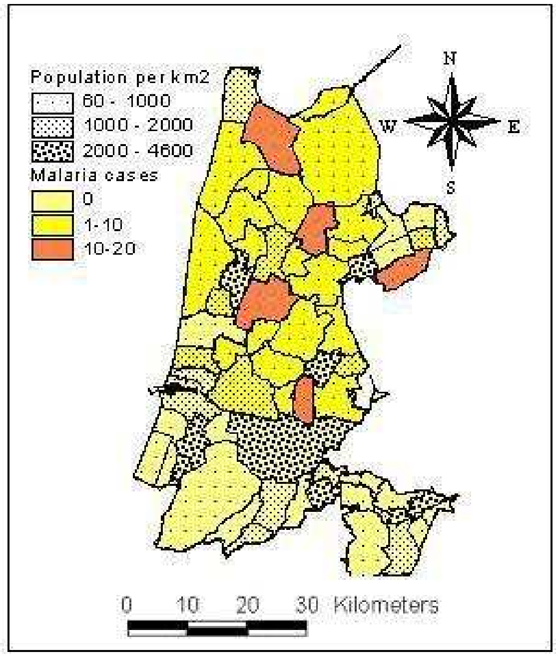


Figure 7.4: Calculated malaria cases of the month July for the years 1934 and 2003, shown with the population density per km^2 per municipality.

From figure 7.4 can be concluded that the malaria risk is low in areas with a high population density. This does not answer the expectation for a moderate population density since the chance that a person gets infected is relatively high. In densely populated urban areas the risk is low as a results of unsuitable living conditions for the mosquitoes.

To know what the output of the model would be when using a high value for the Human Blood Index, calculation with the model is done with a Human Blood Index of 0,5 in stead of the standard value of 0,05. The reason to do a run with this high value is; when getting more recreation in wet areas the biting habits of malaria mosquitoes can change. It is possible that biting humans will get easier and therefore more common than biting animals.

In figure 7.5 the output of the model, when using a Human Blood Index of 0,5 for the month June of the year 2003, is displayed. The number of malaria cases is very high in this case.

Number of malaria cases in June 2003 using a HBI of 0,5

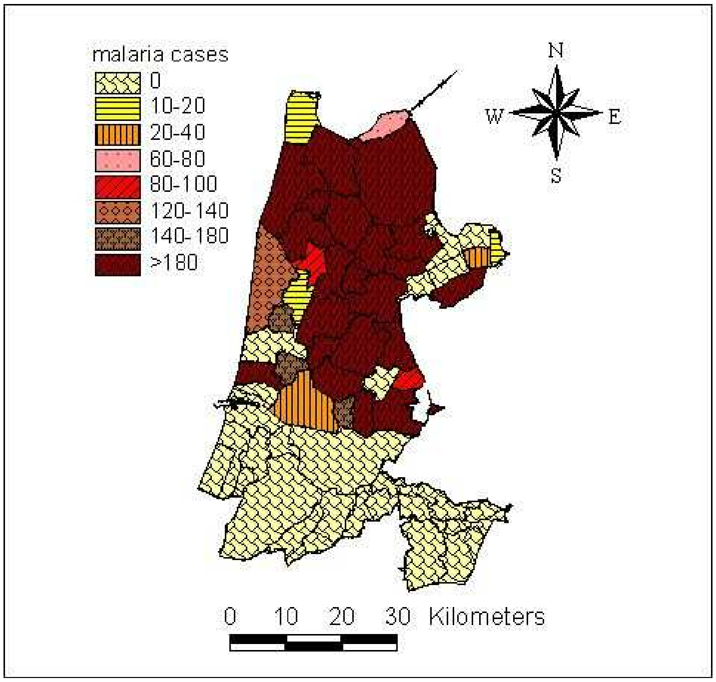


Figure 7.5: Calculated malaria cases of the month June for the year 2003 (HBI = 0,5).

8 Conclusions and discussion

The conclusions of the research can be divided into three parts; the first part contains the conclusions regarding malaria in the Netherlands and the second part contains the conclusions regarding the model and the third part contains a final overall conclusion.

8.1 Malaria in the Netherlands

From the desk study is concluded that malaria theoretically can exist in the Netherlands. Although the plasmodium that causes malaria is extincted and the vector that used to transmit the disease is does not occur in large quantities anymore, there is still the possibility that malaria occurs. There is assumed that as a result of improving environmental conditions the population of the vector can regain sizes and there are indications that a mosquito that is strongly related to the vector in the past also is capable of transmitting the disease. This mosquito, Anopheles messeae, is a mosquito that commonly present in the Netherlands. There can be stated that currently as well as in the future a vector for malaria is present in the Netherlands.
The plasmodium that caused malaria in the Netherlands is Plasmodium vivax, although this plasmodium is extincted in the Netherlands, there is a chance that it will return back. If the plasmodium returns back to the Netherlands it has to be brought along from an other country where Plasmodium vivax is still present. This returning is named the *import of malaria*. In case of import malaria a person that is infected abroad enters the Netherlands and when this person get bitten by a malaria vector than the vector can transmit the disease to other persons. These cases of malaria are the so-called secondary malaria cases.
There are several risk categories of people that might import malaria. Two main categories that are relevant for the situation in the Netherlands are; refugees and tourists. The category refugees is a risk group because the medical care in many “problem” countries like Afghanistan is lacking. Refugees are often kept in central places so the density of potential risk is relatively high. The second category, the tourists, is becoming more and more a risk group. The distances that people travel for holidays are increasing and there are almost no unexploited areas left. Although preventive measures for malaria can be taken full protection is not possible.
One of the problems of the disease malaria is the incubation time. The incubation time is quite long so the disease is often only noted after the return. An other problem is the fact that the symptoms of the disease have strong resemblance with a common flu.
Combining the threat of import malaria and the improving environmental conditions for the vector with some trends in behaviour of the Dutch people, it reasonable to state that the risk for malaria need to be taken serious.

8.2 The malaria model

From the calibration there can be concluded that the model is not yet ready to be applied in practise. During the calibration a deviation ranging between 78 and 100 percent was found. The best match which was found between the actual situation and the calculated situation in 1934 was at a feeding frequency of 0,30 and at a daily mosquito survival rate of 0,79. For the other input variables the initial input values were used (see table 6.7 in Chapter 6). All initial values were used for the first run, this are the values determined by the malaria experts. In this case deviation of the actual situation is ranging from 79 till 227 percent. Based on this calibration the conclusion that no good match was found, is drawn. A good match is considered to be a match that does deviate more than 20%. The model is not ready yet to perform an uncertainty analysis or a validation. Before performing this uncertainty analysis the model should have good calibration results.
Reasons for the differences between the actual and the calculated situation are identified by means of analysing the model parameters.

Model parameters

During the research some problems have been encountered in finding the right data in the right format. Data for the year 1934 appeared to be hard to find. Some data therefore had to be estimated. Together with specialists values for the model variables were determined. The model calculates the vectorial capacity from; the daily biting rate *(a),* the number of mosquitoes per person *(m)*, the daily mosquito survival rate *(p)* and the extrinsic incubation period *(n).*

These parameters are calculated by the model or have to be filled-in in by the user.

Daily biting rate

Calibration of the model is done by changing the feeding frequency and the daily mosquito survival rate. The daily biting rate is determined by the *Human Blood Index* times the *biting frequency* of female mosquitoes on humans. The determination of the daily biting rate is considered to be accurate, however the daily biting rate only can be determined more in detail when more input data is collected. The daily mosquito biting rate can possibly increase because of leisure behaviour of people, when the weather is fine people move to humid places for instance lakes. The chance to get bitten by a mosquito than could gets higher. As can be seen in figure 7.4 of Chapter 7, the malaria risk will increase extremely when a high value for the Human Blood Index (biting ratio on human) is used.

Daily mosquito survival rate

During calibration the daily mosquito survival rate was determined. By running the model with different values the best match was sought. A daily mosquito survival rate of 0,79 gave the best matching results. It is possible for the user to change this value, which is determined by the state variables; number of host animals, number of animal sheds/ stables, the relative humidity and the temperature. The daily mosquito survival rate is calculated by the weights of the mentioned state variables. The user can change the weights to optimise the model.

Number of mosquitoes per person

As can be read in chapter 7 in figure 7.1 the peaks of the results are situated in the wrong district, this error can be caused by two factors. The water surface per municipality or the number of mosquitoes per municipality, both of these state variables are based on estimations. The number of mosquitoes per municipality is calculated and estimated by means of the table made by Van der Torren in 1934. The estimation of the number of mosquitoes per municipality could be less reliable because the method used by Van der Torren was inconsequent, the number of dips taken during his research is not clear and had to be estimated. The calculation factor; number of mosquitoes per person (m) is determined by the number of mosquitoes per m^2 times the m^2 of water surface per km^2 per municipality divided by the number of inhabitants per km^2 per municipality. Factor m is an important part of the model and its accuracy is very important. In the research the reliability of factor m is questionable because of the uncertainty of the number of mosquitoes per m^2 of water surface and the uncertainty of the m^2 of water surface per municipality.

Extrinsic Incubation time

The final calculation factor is the extrinsic incubation time, the extrinsic incubation time is the incubation time of Plasmodium vivax in the malaria mosquito. For the incubation time the average monthly temperature has been used. Below the 15 °C no development of Plasmodium vivax is possible. Since the average monthly temperature has been used for the incubation time, periods of high temperatures can be blanked out by periods of low temperatures in the same month. The incubation time can be variable within one month but on the average only one value will be shown. This value may give a wrong impression. Therefore runs with the maximum temperature were done. Still a minimal deviation of 78% was found, but at least for the months April and May gave an output. To run the model the outdoor temperatures were taken. In history, when people lived in houses connected to the stables, mosquitoes lived inside the houses. In this cases the temperatures were always higher than 15 °C and were therefore suitable for the development of Plasmodium vivax.

Other data

Beside the changes that should be made for the formula data. More data should be gathered for the state variables chloride concentration and vegetation. A lack of data for the Southern part of Noord-Holland for the year 2003 causes the model to give an output of zero malaria cases for this part. To get better output for the year 2003, data for the chloride concentration and vegetation data should be gathered.

8.3 Overall conclusion

During calculation the model assumes Plasmodium vivax is present, so the existence of malaria in the calculated cases is only possible when a Plasmodium vivax carrier is present. The presence of a Plasmodium vivax carrier in the province Noord-Holland is possible. Yearly about 750 cases of import malaria are reported in the Netherlands, from which 40% is Vivax malaria (J.P. Verhave). Approximately 20% of the inhabitant of the Netherlands live in the province Noord-Holland. Because of good medical care almost every case of import malaria on autochthones is noticed before it can be transmitted. It is possible one can carry malaria without noticing the disease this is more like in case of refugees from for example Afghanistan.

Briefly summarized there can be stated that although no perfect match was found, the basis for a model that calculates the malaria risk in Noord- Holland was made. The model functions correctly and the main factors that determine the malaria risk have been mapped out. For malaria experts now the challenge is there to bring up more data, as well in quantity as in quality, to feed the model.

When a good match is found and when the model is ready to be applied, than the model has potential in various contexts. One potential sector is landscape planning. The model can be used to identify risk areas so when decisions have to de made on increasing wetlands, urban areas and leisure at least the factor malaria can be considered. Also for planning centres for refugees it is advisable to consider the risk of malaria. A high density of potential carriers in an area in which many vectors are present may create unnecessary risks.

9 Recommendations

For the continuance of the research the following recommendations are made.

- More accurate data has to be gathered to perform an reliable calibration. Especially for the state variables; water surface in 1934 per municipality and water surface per municipality in the year 2003.

- The number of mosquitoes per m^2 has to be determined for the year 1934 as well as the year 2003. Now data for the number of mosquitoes per m^2 is taken from a research done in the Dutch province Zuid-Holland (Takken e.t. all., 2003).

- The model can be made more accurate by using weekly average temperatures or daily average temperatures, so the incubation time becomes more accurate. It has to be noticed that the calculation are made by a model that represents a simplification of the real situation, so going to far in detail might not always be the solution.

- To obtain more insight to cases of imported malaria it is proposed to conduct research to for instance the number of malaria carriers in refugee centres. Also other factors that can possible be causes of malaria in the Netherlands have to be researched.

- The model should be calibrated further and with newly obtained input data to make it a good tool to calculate the malaria risk in the province Noord-Holland.

- A more detailed survey can be done to the number of suitable sheds/ stables, in the province Noord-Holland, for the malaria mosquito. Also a survey to the number of host animals per municipality is recommended.

- Finally it is recommended continue the research to malaria and optimise the model for its final purpose, the calculation of the malaria risk in Noord-Holland.

10 Bibliography

- **Commissie voor de malariabestrijding**, Verslag van de werkzaamheden der commissie voor de malariabestrijding door de bevolking in Noord-Holland over 1934, 1935.
- **Gaardbo** Kuhn, K, Campbell-Lendrum, D.H., Armstron, B, Davies, C.R., Malaria in Britain: Past, Present, and future, In: *PNAS*, Volume 100, No. 17, August 2003, p9997-10001.
- **Garret-Jones**, C, The human blood index of malaria vectors in relation to epidemiological assessment, *Bull. Wld .Health Org.* **30**,p241 – 261, 1964.
- **Gilles**, H.M, Warrel, D.A., Bruce-Chwatt's essential malariology, Great Britain, 1993.
- **Goethart**, J.W.C., Jongmans, W.J., Plantenkaartjes voor Nederland 1902-1908, 1908.
- **Hest,** N.A.H. van, Smit, F., Verhave, J.P., Sterkte onder rapportage van malaria in Nederland; een vangst-hervangstanalyse, In: *Ned. Tijdschrift voor Geneeskunde*, 2001, 145 (4), p175-179.
- **Jetten**, T.H, Focks, D.A., Changes in the distribution of dengue transmission under climate warning scenarios, Wageningen, 2001, p 1-18.
- **Kaaden**, J.J. van der, Terugkeer van de inheemse malaria in Nederland?, Rockanje, June 1999.
- **Kraan**, H, Malariabestrijding in Noord-Holland, Amsterdam, May 1969.
- **Langran**, G, Time in geographic information systems, 1992.
- **Lindsay**, S.W., Thomas, C.J., Global warning and risk of vivax malaria in Great Britain, In: *Global Change & Human Health*, Volume 2, No 1.,2001, p80-84.
- **Malaria-commisie uit den gezondheidsraad (1934 & 1935),** Verslag over de jaren 1934 en 1935 van de malaria-commisie uit den gezondheidsraad, June 1936.
- **Steenbergen**, H.A., Macrofauna atlas van Noord-Holland, verspreidingskaarten en responsies op milieufactoren van ongewervelde waterdieren, Haarlem, January 1993.
- **Stuiver,** H.J., K075-220 Geo-information tools, Wageningen, November 1999**.**
- **Swellengrebel,** N.H., Buck, A. de, Malaria in the Netherlands, Amsterdam, 1938.
- **Takken**, W, Geene, R, Adam, W, Paaijmans, K, Spitzen, J, Wijans, E, Verhulst, N, Lieshout, M. van, Martens, P, Malaria risico analyse in de Rijn-Maas Delta, 1 June 1999 – 31 May 2003.
- **Takken**, W, Jetten, T.H, Wege, J.J. van de, Potential impact of climatic changes on the ecology and distribution of malaria vectors, 1995.
- **Torren**, G. van der, De zoografische verspreiding van Anopheles maculipennis atroparvus en anopheles maculipennis messeae in westelijk Nederland met het oog op "Species-assaineering", Amsterdam, December 1935.
- **Verhave**, J.P., The disappearance of Dutch malaria and the Rockefeller Foundation, Nijmegen, in*: Parasitologia 42*, 2000, p 111-115.
- **Voogd**, J.H., Multicriteria evaluation for urban and regional planning, Eindhoven, 1982.

- http://chw.noord-holland.nl/ (02-01-2004).
- http://www.hhnk.nl/ (02-01-2004).
- http://www.hhs-agv.nl/ (02-01-2004).
- http://www.knmi.nl/product/ (19-01-2004).
- http://www.Noord-Holland.nl, (17-01-2004).
- http://www.rat.de/kuijsten/atlas/nh/ (12-12-2003).
- http://www.rijkswaterstaat.nl/regio/organisatie/DirectieNoordHolland.asp (02-01-2004).
- http://www.rijnland.net (04-01-2004).
- http://www.rph.wa.gov.au/labs/haem/malaria/, (07-10-2003).
- http://194.151.97.59/ (04-01-2004).
- http://www.wgh.nl/ (02-01-2004).
- http://www.who.int/en/ (22-11-2004).

Appendix 1 Multi-criteria evaluation

A multi-criteria evaluation can serve to inventorize, classify, analyze and conveniently arrange the available information (Voogd, 1982). Multi-criteria evaluation can be used by different users, for example: planners, regional scientists, economics ed. The advantage of multi-criteria evaluation is that from qualitative data quantitative data can be made by giving qualitative data a weight. This weight is determined by mixed evaluation matrixes. First the data priorities have to be determined.

	Existence of mosquitoes
Temperature	1
Relative humidity	1
Host animals	2
Animal sheds /stables	2

Table1: Priority table

To determine the weights an evaluation matrix is made to determine the impact of different criteria on the existence of mosquitoes.

Criteria	
	Existence of mosquitoes
Temperature < 10	Unsuitable
Temperature 10-20	Suitable
Temperature 20-30	Optimal
Temperature > 30	Unsuitable
Host animals < 1	Unsuitable
Host animals 1-10	Suitable
Animal sheds >10	Optimal
Animal sheds < 1	Unsuitable
Animal sheds 1-10	Suitable
Animal sheds >10	Optimal
Relative humidity < 60	Not suitable
Relative humidity > 60	Suitable

Table2: Example of the evaluation matrix

The weights have to be determined with the help of the priority and the evaluation matrixes. The criteria with the highest value will get the highest weight. Sometimes the evaluation matrix gives a clear view about the priority of one alternative no further analyses is necessary in that case. But if many conflicting parameters are used, it is impossible to determine the priority of the different cases in once.
A priority matrix has to be made.

Criteria		
	Existence of mosquitoes	**Priority**
Temperature 20-30	Optimal	1
Relative humidity > 60	Suitable / Optimal	1
Temperature 10-20	Suitable	2
Animal sheds >10	Optimal	3
Animal sheds >10	Optimal	3
Host animals 1-10	Suitable	4
Animal sheds 1-10	Suitable	4
Host animals < 1	Unsuitable	5
Animal sheds < 1	Unsuitable	5
Temperature < 10	Unsuitable	5
Relative humidity < 60	Unsuitable	5
Temperature > 30	Unsuitable	5

Table3: Priority matrix of all criteria

The criteria with priority 5 will get a weight of zero because the criteria are unsuitable. Weights have to be assigned to the other parameters by a weighting method.
The direct system description method is used, in this method a measurable characteristic is represented by the weights of the different criteria. In this case the weights of the criteria multiplied represent the daily biting rate. This daily biting rate can be determined by malaria experts.

Appendix 2 State variables

Database input file for the year 1934

MUNID	MUNNAME	AREAKM2	M2DITCH	HANIMAL	ANSHEDS	POP_MUN
62	WIERINGEN	27	246400			6324
63	DEN HELDER	47	222500			32326
67	WIERINGERMEER	206	1084000			7000
68	ANNA PAULOWNA	77	1992000			5810
71	ZIJPE	97	1215000			6510
75	SCHAGEN	19	680000			4106
76	NIEDORP	63	1123200			8292
79	HARENKARSPEL	55	720000			6982
81	MEDEMBLIK	8	96000			5397
82	NOORDER-KOGGENLAND	51	1137600			5110
83	BERGEN NH	98	938000			13843
84	WERVERSHOOF	24	360000			3520
85	OPMEER	42	2040600			4689
86	ANDIJK	23	50000			4281
87	ENKHUIZEN	13	84000			9511
88	LANGEDIJK	27	540000			11265
89	HEERHUGOWAARD	40	720000			5025
90	STEDE BROEC	16	110000			7282
91	DRECHTERLAND	24	474000			5768
92	WOGNUM	21	728000			3626
93	OBDAM	21	327000			2780
95	VENHUIZEN	36	1155000			4281
96	ALKMAAR	31	170000			31004
98	HOORN	20	420000			14023
100	WESTER-KOGGENLAND	62	1040000			6131
105	SCHERMER	64	840000			2866
106	HEILOO	19	502400			5646
109	BEEMSTER	72	1107000			5249
110	ZEEVANG	40	522000			2890
114	CASTRICUM	55	850000			10047
116	GRAFT-DE RIJP	22	333000			2551
117	UITGEEST	22	388000			4044
119	WORMERLAND	45	860000			6022
120	HEEMSKERK	28	770000			4573
121	PURMEREND	25	938000			6136
122	EDAM-VOLENDAM	17	432000			8496
124	ZAANSTAD	83	1122000			60631
126	BEVERWIJK	19	350000			17170
128	WATERLAND	56	800000			8142
129	VELSEN	47	312000			43073
130	LANDSMEER	27	1152000			3723
132	OOSTZAAN	16	300000			3930
141	BLOEMENDAAL	39	48400			14999
143	HAARLEMMERLIEDE CA	21	864000			3164
144	AMSTERDAM	173	2450000			684778
145	HAARLEM	32	329000			124855
149	ZANDVOORT	34	4000			8410
152	HAARLEMMERMEER	185	6800000			27891

155	HEEMSTEDE	10	65000			15779
156	DIEMEN	13	240000			4987
159	MUIDEN	15	216000			2867
160	OUDER-AMSTEL	26	490000			4239
163	AMSTERDAM	22	400000			87586
164	AMSTELVEEN	44	1170000			13427
167	BENNEBROEK	2	30000			2259
169	NAARDEN	24	207200			6314
171	WEESP	22	309600			31004
176	HUIZEN	16	20000			8713
178	AALSMEER	32	288000			9317
179	BLARICUM	11	18200			3001
186	HILVERSUM	46	400000			62319
187	WIJDEMEREN	77	3000000			6011
188	BUSSUM	8	0			26239
193	LAREN	12	248			7118
194	UITHOORN	19	1206000			3959

Database input file for the year 2003

MUNID	MUNNAME	AREAKM2	M2DITCH	HANIMAL	ANSHEDS	POP_MUN
62	WIERINGEN	27	176000			8358
63	DEN HELDER	47	178000			60026
67	WIERINGERMEER	206	1084000			12626
68	ANNA PAULOWNA	77	664000			13940
71	ZIJPE	97	810000			11314
75	SCHAGEN	19	340000			17488
76	NIEDORP	63	624000			11554
79	HARENKARSPEL	55	288000			15793
81	MEDEMBLIK	8	32000			7902
82	NOORDER-KOGGENLAND	51	632000			10456
83	BERGEN NH	98	670000			31742
84	WERVERSHOOF	24	200000			8470
85	OPMEER	42	1074000			11220
86	ANDIJK	23	10000			6390
87	ENKHUIZEN	13	28000			17117
88	LANGEDIJK	27	90000			25009
89	HEERHUGOWAARD	40	360000			46898
90	STEDE BROEC	16	22000			21171
91	DRECHTERLAND	24	316000			10194
92	WOGNUM	21	364000			8132
93	OBDAM	21	218000			6629
95	VENHUIZEN	36	462000			7879
96	ALKMAAR	31	68000			93390
98	HOORN	20	140000			67515
100	WESTER-KOGGENLAND	62	520000			13765
105	SCHERMER	64	840000			4849
106	HEILOO	19	125600			22048
109	BEEMSTER	72	738000			8536
110	ZEEVANG	40	522000			6324
114	CASTRICUM	55	340000			35327
116	GRAFT-DE RIJP	22	222000			6345
117	UITGEEST	22	194000			11772
119	WORMERLAND	45	344000			15510

120	HEEMSKERK	28	110000			36421
121	PURMEREND	25	134000			74921
122	EDAM-VOLENDAM	17	144000			28063
124	ZAANSTAD	83	660000			139464
126	BEVERWIJK	19	50000			36409
128	WATERLAND	56	800000			17150
129	VELSEN	47	78000			67527
130	LANDSMEER	27	192000			10352
132	OOSTZAAN	16	50000			9118
141	BLOEMENDAAL	39	44000			17045
143	HAARLEMMERLIEDE CA	21	216000			5533
144	AMSTERDAM	173	490000			653036
145	HAARLEM	32	94000			147097
149	ZANDVOORT	34	4000			16864
152	HAARLEMMERMEER	185	1700000			122902
155	HEEMSTEDE	10	26000			25760
156	DIEMEN	13	96000			24046
159	MUIDEN	15	216000			6647
160	OUDER-AMSTEL	26	350000			13054
163	AMSTERDAM	22	40000			83526
164	AMSTELVEEN	44	390000			78095
167	BENNEBROEK	2	6000			5307
169	NAARDEN	24	148000			16947
171	WEESP	22	258000			17885
176	HUIZEN	16	2000			42125
178	AALSMEER	32	192000			22839
179	BLARICUM	11	14000			9309
186	HILVERSUM	46	40000			83306
187	WIJDEMEREN	77	600000			23237
188	BUSSUM	8	0			31267
193	LAREN	12	248			11674
194	UITHOORN	19	134000			26680

This are the input database files, the column names have to stay the same and the file has to be saved with the dbf (IV) extension. The number of host animals and the number of animal sheds and stables are not known but in the research they are estimated.

Maximum temperature

Year	**March**	**April**	**May**	**June**	**July**	**August**	**September**
1934	9,1	16,2	17,8	22,1	23,8	21,5	21,6
1992	10,0	12,8	21,0	22,3	23,1	22,5	19,2
2003	12,8	15,5	18,2	23,7	24,5	25,4	20,6

Minimum temperature

Year	**March**	**April**	**May**	**June**	**July**	**August**	**September**
1934	0,9	5,1	6,2	9,8	11,5	11,0	10,2
1992	3,5	4,1	9,7	12,2	13,2	13,3	10,4
2003	1,9	3,4	7,6	10,8	12,4	12,6	7,4

Average temperature

Year	**March**	**April**	**May**	**June**	**July**	**August**	**September**
1934	4,8	10,3	12,1	15,9	17,7	16,2	16,0
1992	6,9	8,7	15,6	17,2	18,3	17,8	14,6
2003	7,3	9,9	13,2	17,8	18,8	19,3	13,9

Rainfall per day in the year 1934

Day	**March**	**April**	**May**	**June**	**July**	**August**	**September**
1	0,1	0,0	**22,5**	0,0	0,0	6,1	0,1
2	0,1	0,0	3,8	0,0	0,0	11,3	0,0
3	2,2	0,0	3,7	0,0	0,0	0,0	1,4
4	0,0	0,0	4,3	0,0	0,0	2,5	0,0
5	1,3	0,0	1,0	0,0	0,0	0,1	0,0
6	13,8	0,0	0,0	6,6	0,0	0,0	0,1
7	0,2	0,4	0,6	4,2	0	0,0	0,0
8	0,0	1,1	16,5	0,0	0,0	0,0	4,6
9	0,1	1,7	5,5	0,0	0,0	5,4	3,5
10	0,0	0,2	0,0	0,0	0,0	0,0	0,0
11	4,1	0,0	0,0	0,0	0,0	1,2	0,0
12	0,2	0,0	0,0	0,0	0,2	**37,9**	0,0
13	5,7	0,0	0,0	0,0	1,1	19,3	0,0
14	3,2	0,0	5,5	0,0	3,5	1,3	0,0
15	2,8	0,1	0,7	0,0	1,3	0,0	0,1
16	2,2	5,4	4,3	0,0	0,0	0,0	0,0
17	5,1	10,0	1,0	0,0	0,0	0,3	0,0
18	3,1	9,8	0,0	0,0	0,0	0,0	0,6
19	2,1	2,8	0,0	0,3	0,0	0,1	6,6
20	7,7	0,0	0,0	0,1	0,0	0,0	5,5
21	1,1	0,0	0,0	1,7	2,0	0,0	2,9
22	0,3	0,0	0,0	3,7	0,0	0,1	9,4
23	1,5	0,1	0,0	0,0	0,0	1,6	1,9
24	0,0	0,2	0,0	1,3	1,2	0,3	1,2
25	0,0	1,4	0,0	1,3	0,0	0,0	0,0
26	0,0	8,0	0,0	2,8	8,0	0,1	0,0
27	0,1	1,2	0,0	0,0	0,1	0,0	0,6
28	0,0	1,0	0,0	18,9	2,8	0,0	0,0
29	0,0	0,0	0,0	0,2	**25,6**	8,4	0,0
30	0,0	0,0	0,0	0,0	0,2	5,9	0,2
31	0,0		0,0		7,1	1,1	

Rainfall per day in the year 1992

Day	**March**	**April**	**May**	**June**	**July**	**August**	**September**
1	0,0	0,0,2	15,4	4,0	<0,05	<0,05	7,9
2	1,9	1,2	0,2	15,9	0,6	0,0	3,4
3	<0,05	3,7	0,1	0,8	**26,5**	0,3	7,9
4	<0,05	<0,05	0,0	8,9	7,4	0,4	16,7
5	2,7	<0,05	0,0	7,3	0,1	0,0	11,8
6	3,4	<,0,05	0,0	<0,05	0,0	<0,05	0,0
7	0,0	<0,05	<0,05	8,4	0,0	0,0	0,6
8	<0,05	0,0	5,0	9,9	0,0	2,9	0,4
9	<0,05	0,0	15,2	1,6	0,0	6,5	0,0
10,0	3,0	0,0	4,3	0,0	0,4	**25,9**	0,0
11	<0,05	0,0	0,5	0,0	0,1		0,1
12	18,7	1,4	<0,05	<0,05	2,2	2,9	0,0
13	10,2	1,5	0,0	0,0	9,0	**23,4**	2,2
14	8,0	1,9	0,0	0,0	9,0	**25,7**	0,0
15	0,5	4,1	0,0	0,0	0,0	0,0	0,0
16	<0,05	6,6	0,0	0,0	<0,05	6,0	0,0
17	0,0	9,4	0,0	0,0	0,9	<0,05	0,0
18	0,3	2,1	0,0	2,9	<0,05	<0,05	0,2
19	<0,05	0,4	0,0	1,9	0,0	5,8	<0,05
20,0	2,6	0,0	0,0	0,0	0,0	**20,1**	4,0
21	4,3	0,0	0,0	0,0	3,7	0,1	<0,05
22	8,8	<0,05	0,0	<0,05	<0,05	2,0	0,7
23	2,1	0,9	<0,05	0,0	0,0	0,7	0,2
24	0,3	0,0		0,0	0,3	3,7	<0,05
25	1,0	2,5	<0,05	0,0	0,0	6,9	0,0
26	5,6	6,1	0,0	0,0	0,0	3,3	0,0
27	0,8	0,0	0,0	0,0	1,4	<0,05	0,0
28	0,4	8,1	0,0	0,0	<0,05	1,8	0,0
29	0,2	0,0	0,5	0,0	0,0	7,5	0,0
30,0	2,9	1,9	1,7	1,0	0,0	8,9	0,7
31	3,7		0,1		0,0	6,5	

Rainfall per day in the year 2003

Day	**March**	**April**	**May**	**June**	**July**	**August**	**September**
1	0,2	15,7	0,6	0,0	4,1	0,0	1,1
2	3,1	3,6	9,2	10,8	5,7	<0,05	0,2
3	0,0	<0,05	2,1	<0,05	5,1	0,0	0,0
4	0,9	<0,05	0,0	3,5	0,7	0,0	0,0
5	0,3	<0,05	7,3	<0,05	<0,05	0,0	0,0
6	1,5	0,0	3,6	0,0	0,0	<0,05	1,7
7	0,9	0,0	0,0	0,0	<0,05	0,0	0,0
8	8,5	0,0	0,8	7,5	1,5	0,0	<0,05
9	0,6	0,4	<0,05	0,0	<0,05	0,0	3,0
10	0,0	<0,05	0,0	7,7	0,0	0,0	13,5
11	7,2	0,1	1,0	0,0	0,0	0,0	0,0
12	0,3	0,0	11,5	<0,05	0,0	0,0	0,1
13	0,0	0,0	2,0	0,0	0,0	0,0	0,0
14	0,0	0,0	1,0	0,0	0,0	<0,05	0,0
15	0,0	0,0	2,0	0,0	0,0	0,0	0,0
16	0,0	0,0	<0,05	0,0	<0,05	0,0	0,0
17	0,0	0,0	2,4	1,3	8,5	0,1	0,0
18	0,0	0,0	3,2	<0,05	0,3	0,5	0,0
19	0,0	<0,05	3,4	0,2	0,0	0,0	0,0
20	0,0	<0,05	**22,4**	0,0	0,2	<0,05	0,0
21	0,0	3,9	2,8	0,0	<0,05	0,0	0,0
22	0,0	0,1	3,0	0,1	0,0	<0,05	14,5
23	0,0	0,0	9,4	0,2	0,0	<0,05	12
24	0,0	<0,05	2,4	0,0	0,1	0,0	<0,05
25	0,0	1,4	1,8	0,0	1,7	0,0	0,0
26	0,0	11,9	0,0	0,0	<0,05	<0,05	0,4
27	0,0	0,8	0,0	0,0	0,,6	0,0	<0,05
28	0,0	1,1	0,0	<0,05	0,3	1,4	4,6
29	<0,05	3,0	0,0	0,0	0,0	5,5	0,5
30	0,0	4,2	0,0	3,3	1,0	<0,05	0,0
31	0,0		0,0		0,0	1,7	

Appendix 3 Calculated mosquitoes for the year 1934

Estimated number of mosquitoes per location

			Measured by Van der Torren					
Map code	Hourbox code	Quaterbox code	atroparvus	messeae	nr per dip	estimated nr dips	messeae/dip	atroparvus/dip
K4	13	21	0	0	0	0	0,0	0,0
K4	13	31	0	0	0	0	0,0	0,0
K4	13	43	21	0	14	10	0,0	2,1
K4	23	13	4	0	7	10	0,0	0,4
K4	23	44	39	0	3	30	0,0	1,3
K4	24	33	28	1	8	10	0,1	2,8
K4	24	42	12	0	0	0	0,0	0,0
K4	32	23	9	0	18	10	0,0	0,9
K4	32	34	23	0	5	10	0,0	2,3
K4	32	42	34	0	10	10	0,0	3,4
K4	33	11	32	0	25	10	0,0	3,2
K4	34	23	0	0	0	0	0,0	0,0
K4	35	11	36	1	4	10	0,3	3,6
K4	35	33	27	2	3	30	0,7	0,9
K4	42	23	32	0	13	10	0,0	3,2
K4	42	24	34	2	16	10	0,1	3,4
K4	43	21	36	0	11	10	0,0	3,6
K4	43	22	23	0	4	10	0,0	2,3
K4	43	32	25	0	12	10	0,0	2,5
K4	44	14	36	0	4	10	0,0	3,6
K4	44	34	36	0	5	10	0,0	3,6
K4	45	33	16	0	9	10	0,0	1,6
K4	52	14	64	1	3	30	0,3	2,1
K4	52	33	36	0	46	5	0,0	7,2
K4	53	11	36	0	4	10	0,0	3,6
K4	53	13	38	0	12	10	0,0	3,8
K4	53	24	14	0	3	30	0,0	0,5
K4	53	44	6	0	12	10	0,0	0,6
K4	54	41	30	0	8	10	0,0	3,0
K4	54	44	24	0	5	10	0,0	2,4
K4	55	12	27	3	7	10	0,4	2,7
K4	55	32	30	0	10	10	0,0	3,0
K4	57	42	19	1	23	10	0,0	1,9
K4	57	43	19	12	7	10	1,7	1,9
K4	62	12	28	0	1	30	0,0	0,9
K4	62	13	6	0	7	10	0,0	0,6
K4	62	14	36	0	17	10	0,0	3,6
K4	62	21	32	0	7	10	0,0	3,2
K4	62	23	40	0	7	10	0,0	4,0
K4	62	31	0	11	1	30	11,0	0,0
K4	62	43	35	1	6	10	0,2	3,5
K4	62	44	0	17	1	30	17,0	0,0
K4	63	13	36	6	8	10	0,8	3,6
K4	63	14	23	18	9	10	2,0	2,3
K4	63	21	15	0	13	10	0,0	1,5
K4	63	24	21	0	23	10	0,0	2,1

K4	63	41	24	0	10	10	0,0	2,4
K4	63	42	33	0	2	30	0,0	1,1
K4	63	44	30	0	11	10	0,0	3,0
K4	64	12	33	0	7	10	0,0	3,3
K4	64	22	10	0	23	10	0,0	1,0
K4	64	31	30	0	28	10	0,0	3,0
K4	64	33	47	1	5	10	0,2	4,7
K4	64	41	39	1	17	10	0,1	3,9
K4	64	42	26	0	15	10	0,0	2,6
K4	64	43	35	1	62	5	0,0	7,0
K4	65	11	29	0	2	30	0,0	1,0
K4	65	12	24	0	50	5	0,0	4,8
K4	65	22	28	0	13	10	0,0	2,8
K4	65	43	16	2	7	10	0,3	1,6
K4	65	44	24	0	26	10	0,0	2,4
K4	66	14	23	0	21	10	0,0	2,3
K4	66	21	18	3	3	30	1,0	0,6
K4	66	31	17	0	10	10	0,0	1,7
K4	67	31	43	0	13	10	0,0	4,3
K4	67	43	1	9	4	10	2,3	0,1
K4	67	44	16	3	13	10	0,2	1,6
K4	68	43	0	21	4	10	5,3	0,0
K5	61	23	10	0	5	10	0,0	1,0
K5	61	33	77	2	32	5	0,1	15,4
L4	12	12	7	33	19	10	1,7	0,7
L4	12	21	2	27	4	10	6,8	0,2
L4	12	42	8	35	4	10	8,8	0,8
L4	12	43	25	12	16	10	0,8	2,5
L4	14	11	23	0	10	10	0,0	2,3
L4	14	14	50	0	20	10	0,0	5,0
L4	14	23	36	0	137	5	0,0	7,2
L4	14	24	51	0	2	30	0,0	1,7
L4	14	33	0	0	0	0	0,0	0,0
L4	14	42	12	0	131	5	0,0	2,4
L4	14	43	28	1	24	10	0,0	2,8
L4	15	11	24	0	22	10	0,0	2,4
L4	15	24	36	0	41	5	0,0	7,2
L4	15	31	35	0	20	10	0,0	3,5
L4	15	34	30	0	32	5	0,0	6,0
L4	15	41	48	1	5	10	0,2	4,8
L4	16	13	26	0	7	10	0,0	2,6
L4	16	21	26	1	9	10	0,1	2,6
L4	16	31	20	0	3	30	0,0	0,7
L4	16	34	13	9	2	30	4,5	0,4
L4	16	41	21	1	5	10	0,2	2,1
L4	16	42	50	0		0	0,0	0,0
L4	16	44	34	1	8	10	0,1	3,4
L4	17	11	29	1	21	10	0,0	2,9
L4	17	32	1	15	2	30	7,5	0,0
L4	17	41	0	33	6	10	5,5	0,0
L4	17	44	0	13	1	30	13,0	0,0
L4	18	32	32	6	12	10	0,5	3,2

L4	18	43	0	3	0	0	0,0	0,0
L4	22	21	26	2	3	30	0,7	0,9
L4	22	24	35	1	6	10	0,2	3,5
L4	22	31	2	33		0	0,0	0,0
L4	22	32	39	1	10	10	0,1	3,9
L4	22	41	36	2	8	10	0,3	3,6
L4	22	42	27	0	10	10	0,0	2,7
L4	22	44	34	1	4	10	0,3	3,4
L4	23	11	33	3	2	30	1,5	1,1
L4	23	21	0	4	0	0	0,0	0,0
L4	23	24	34	0	23	10	0,0	3,4
L4	23	42	40	0	5	10	0,0	4,0
L4	23	43	18	0	1	30	0,0	0,6
L4	23	44	20	0	13	10	0,0	2,0
L4	24	14	30	0	24	10	0,0	3,0
L4	24	21	0	0	0	0	0,0	0,0
L4	24	24	0	0	0	0	0,0	0,0
L4	24	32	22	2	10	10	0,2	2,2
L4	24	34	33	0	11	10	0,0	3,3
L4	24	43	36	0	297	5	0,0	7,2
L4	24	44	38	0	8	10	0,0	3,8
L4	25	11	33	0	40	5	0,0	6,6
L4	25	12	24	0	12	10	0,0	2,4
L4	25	13	0	22	1	30	22,0	0,0
L4	25	22	11	1	11	10	0,1	1,1
L4	25	23	11	6	13	10	0,5	1,1
L4	25	24	15	15	13	10	1,2	1,5
L4	25	31	1	34	3	30	11,3	0,0
L4	25	42	2	31	3	30	10,3	0,1
L4	26	34	43	8	7	10	1,1	4,3
L4	26	42	8	29	7	10	4,1	0,8
L4	26	43	34	8	2	30	4,0	1,1
L4	27	13	3	31	1	30	31,0	0,1
L4	27	43	9	32	6	10	5,3	0,9
L4	28	24	32	0	4	10	0,0	3,2
L4	28	32	0	15	2	30	7,5	0,0
L4	28	43	63	3	37	5	0,1	12,6
L4	32	11	30	0	19	10	0,0	3,0
L4	32	12	34	1	7	10	0,1	3,4
L4	32	13	4	23	1	30	23,0	0,1
L4	32	21	22	17	9	10	1,9	2,2
L4	32	22	42	0	4	10	0,0	4,2
L4	32	24	30	0	24	10	0,0	3,0
L4	32	31	50	0	18	10	0,0	5,0
L4	32	32	19	0	13	10	0,0	1,9
L4	32	43	29	6	28	10	0,2	2,9
L4	32	44	35	1	8	10	0,1	3,5
L4	33	12	17	1	10	10	0,1	1,7
L4	33	14				0	0,0	0,0
L4	33	23	10	0	13	10	0,0	1,0
L4	33	31	36	0	15	10	0,0	3,6
L4	33	32	36	0	2	30	0,0	1,2

L4	33	42	40	0	7	10	0,0	4,0
L4	33	43	29	1	3	30	0,3	1,0
L4	34	11	36	1	32	5	0,0	7,2
L4	34	12	33	1	8	10	0,1	3,3
L4	34	13				0	0,0	0,0
L4	34	14	17	1		0	0,0	0,0
L4	34	21	41	0	7	10	0,0	4,1
L4	34	22	31	0	10	10	0,0	3,1
L4	34	23				0	0,0	0,0
L4	34	24	36	0	5	10	0,0	3,6
L4	33	34	40	0	5	10	0,0	4,0
L4	34	31	38	0	2	30	0,0	1,3
L4	34	32				0	0,0	0,0
L4	34	33				0	0,0	0,0
L4	34	34	39	0	7	10	0,0	3,9
L4	34	42	0	0	0	0	0,0	0,0
L4	34	43	40	0	7	10	0,0	4,0
L4	34	44	0	0	0	0	0,0	0,0
L4	35	11	19	2	1	30	2,0	0,6
L4	35	12	19	16		0	0,0	0,0
L4	35	13				0	0,0	0,0
L4	35	21	0	33	4	10	8,3	0,0
L4	35	22	1	37	1	30	37,0	0,0
L4	35	31				0	0,0	0,0
L4	35	33	31	2	66	5	0,0	6,2
L4	35	34	0	0	0	0	0,0	0,0
L4	35	41	15	0	3	30	0,0	0,5
L4	35	42	18	20	17	10	1,2	1,8
L4	35	43	18	27	4	10	6,8	1,8
L4	35	44	0	0	0	0	0,0	0,0
L4	36	11	4	28	2	30	14,0	0,1
L4	36	21	1	21	1	30	21,0	0,0
L4	36	22	25	6	5	10	1,2	2,5
L4	36	32	46	1	1	30	1,0	1,5
L4	36	33	20	0	3	30	0,0	0,7
L4	38	14	27	1	3	30	0,3	0,9
L4	42	11	32	1	2	30	0,5	1,1
L4	42	13	2	19	3	30	6,3	0,1
L4	43	13	34	0	10	10	0,0	3,4
L4	43	14	14	0	1	30	0,0	0,5
L4	43	21				0	0,0	0,0
L4	43	22	36	0	116	5	0,0	7,2
L4	43	24	34	0	3	30	0,0	1,1
L4	43	33	38	0	3	30	0,0	1,3
L4	43	41	0	0	0	0	0,0	0,0
L4	43	42	45	0	2	30	0,0	1,5
L4	43	43	31	2	2	30	1,0	1,0
L4	44	11	0	0	0	0	0,0	0,0
L4	44	12	15	0	9	10	0,0	1,5
L4	44	13	35	0	25	10	0,0	3,5
L4	44	14	39	0	11	10	0,0	3,9
L4	44	21	34	6	5	10	1,2	3,4

L4	44	22	24	0	18	10	0,0	2,4
L4	44	32	34	1	4	10	0,3	3,4
L4	44	42	49	1	1	30	1,0	1,6
L4	44	43				0	0,0	0,0
L4	44	44	36	0	14	10	0,0	3,6
L4	45	11	15	17		0	0,0	0,0
L4	45	12				0	0,0	0,0
L4	45	13	7	1	57	5	0,0	1,4
L4	45	14	0	0	0	0	0,0	0,0
L4	45	22				0	0,0	0,0
L4	45	24				0	0,0	0,0
L4	45	31				0	0,0	0,0
L4	45	34	36	0		0	0,0	0,0
L4	45	42	36	0	12	10	0,0	3,6
L4	45	43				0	0,0	0,0
L4	46	13				0	0,0	0,0
L4	46	14	0	0	0	0	0,0	0,0
L4	46	21	23	4	1	30	4,0	0,8
L4	46	31	26	1	8	10	0,1	2,6
L4	46	34	17	0	3	30	0,0	0,6
L4	46	41	0	0	0	0	0,0	0,0
L4	52	11	28	7	5	10	1,4	2,8
L4	52	12	35	1	15	10	0,1	3,5
L4	52	22	36	0	51	5	0,0	7,2
L4	52	32	35	1	26	10	0,0	3,5
L4	52	43	55	1	8	10	0,1	5,5
L4	53	12	36	0	33	5	0,0	7,2
L4	53	21				0	0,0	0,0
L4	53	24	40	0	15	10	0,0	4,0
L4	53	42	15	0	20	10	0,0	1,5
L4	53	43	9	0	3	30	0,0	0,3
L4	54	11	32	0	2	30	0,0	1,1
L4	54	13	36	0	10	10	0,0	3,6
L4	54	14	35	0	17	10	0,0	3,5
L4	54	21	36	0	33	5	0,0	7,2
L4	54	22	33	0	123	5	0,0	6,6
L4	54	23	0	0	0	0	0,0	0,0
L4	54	32	30	0	64	5	0,0	6,0
L4	54	41	37	0		0	0,0	0,0
L4	54	42	36	0	141	5	0,0	7,2
L4	54	43				0	0,0	0,0
L4	55	13	23	1		0	0,0	0,0
L4	55	21	0	0	0	0	0,0	0,0
L4	55	23	36	0	8	10	0,0	3,6
L4	55	32	0	0	0	0	0,0	0,0
L4	55	33	30	0	5	10	0,0	3,0
L4	55	42				0	0,0	0,0
L4	55	43	20	0	2	30	0,0	0,7
L4	55	44	28	0		0	0,0	0,0
L4	56	11	0	0	0	0	0,0	0,0
L4	56	13	0	0	0	0	0,0	0,0
L4	56	14	15	2	18	10	0,1	1,5

L4	56	42	14	2	1	30	2,0	0,5
L4	61	23	0	2	0	0	0,0	0,0
L4	62	32	0	22	4	10	5,5	0,0
L4	62	21	38	2	31	5	0,1	7,6
L4	63	14	27	1	8	10	0,1	2,7
L4	63	23	24	2	2	30	1,0	0,8
L4	63	34	45	2	3	30	0,7	1,5
L4	63	41	16	0	15	10	0,0	1,6
L4	64	21	26	0	10	10	0,0	2,6
L4	64	32	20	0	8	10	0,0	2,0
L4	64	41	2	0	11	10	0,0	0,2
L4	65	11				0	0,0	0,0
L4	65	12	30	0	49	5	0,0	6,0
L4	65	14	22	0	12	10	0,0	2,2
L4	65	21	0	0	0	0	0,0	0,0
L4	65	22				0	0,0	0,0
L4	65	23	0	0	0	0	0,0	0,0
L4	65	24	9	1	1	30	1,0	0,3
L4	65	34	56	0	7	10	0,0	5,6
L4	65	44	35	0	3	30	0,0	1,2
L4	66	12	26	0	10	10	0,0	2,6
L4	66	23	31	2	2	30	1,0	1,0
L4	66	43	40	1	12	10	0,1	4,0
L4	67	11	27	5	15	10	0,3	2,7
L4	67	12	32	2	3	30	0,7	1,1
L5	11	14	19	1	7	10	0,1	1,9
L5	11	41	24	0	7	10	0,0	2,4
L5	11	31	45	1	9	10	0,1	4,5
L5	12	11	14	1	1	30	1,0	0,5
L5	21	12	23	0	4	10	0,0	2,3
L5	21	23	13	4	3	30	1,3	0,4
L5	21	34	17	2	5	10	0,4	1,7
M3	48	34	0	0	0	0	0,0	0,0
M3	48	43	3	1		0	0,0	0,0
M3	58	21	1	7	0	0	0,0	0,0
M3	68	11	3	5	0	0	0,0	0,0
N5	12	13	4	30		0	0,0	0,0
N5	12	31	1	25		0	0,0	0,0
M4	12	13	0	0	0	0	0,0	0,0
M4	12	42	49	2	20	10	0,1	4,9
M4	13	11	1	0	0	0	0,0	0,0
M4	13	22	26	0	3	30	0,0	0,9
M4	13	32	19	0	1	30	0,0	0,6
M4	13	41	16	5	1	30	5,0	0,5
M4	14	14	36	0	4	10	0,0	3,6
M4	14	21	14	0	5	10	0,0	1,4
M4	14	31	13	4	25	10	0,2	1,3
M4	15	21	30	2	1	30	2,0	1,0
M4	15	24	35	0	1	30	0,0	1,2
M4	16	11	31	0	5	10	0,0	3,1
M4	16	14	43	0	5	10	0,0	4,3
M4	16	33	16	0	2	30	0,0	0,5

M4	17	31	15	0	25	10	0,0	1,5
M4	17	44	30	0	5	10	0,0	3,0
M4	21	42	5	2	12	10	0,2	0,5
M4	22	33	11	0	1	30	0,0	0,4
M4	24	24	1	1	0	0	0,0	0,0
M4	24	32	26	0	1	30	0,0	0,9
M4	25	22	35	0	2	30	0,0	1,2
M4	25	32	21	1	1	30	1,0	0,7
M4	26	22	25	0	24	10	0,0	2,5
M4	26	32	23	0	16	10	0,0	2,3
M4	26	33	20	2	1	30	2,0	0,7
M4	27	11	0	0	0	0	0,0	0,0
M4	27	34	23	0	2	30	0,0	0,8
M4	32	12	24	0	1	30	0,0	0,8
M4	32	31	31	1	1	30	1,0	1,0
M4	32	43	19	0	2	30	0,0	0,6
M4	33	14	29	4	1	30	4,0	1,0
M4	33	42	20	0	4	10	0,0	2,0
M4	34	32	16	1	1	30	1,0	0,5
M4	35	21	31	0	3	30	0,0	1,0
M4	36	11	15	5	2	30	2,5	0,5
M4	36	14	23	1	5	10	0,2	2,3
M4	36	32	27	3	4	10	0,8	2,7
M4	36	33	34	1	2	30	0,5	1,1
M4	41	21	26	0	25	10	0,0	2,6
M4	41	41	47	0	54	5	0,0	9,4
M4	41	44	14	0	5	10	0,0	1,4
M4	42	14	21	0	23	10	0,0	2,1
M4	42	22	19	0	11	10	0,0	1,9
M4	43	21	21	1	2	30	0,5	0,7
M4	43	42	6	24	5	10	4,8	0,6
M4	43	31	23	0	8	10	0,0	2,3
M4	43	34	34	1	20	10	0,1	3,4
M4	45	43	23	0	3	30	0,0	0,8
M4	46	33	3	25	2	30	12,5	0,1
M4	51	13	8	25	20	10	1,3	0,8
M4	51	41	0	33	3	30	11,0	0,0
M4	52	21	14	0	10	10	0,0	1,4
M4	52	22	26	0	5	10	0,0	2,6
M4	52	31	15	0	3	30	0,0	0,5
M4	53	24	38	6	5	10	1,2	3,8
M4	53	41	18	2	17	10	0,1	1,8
M4	54	12	18	3	8	10	0,4	1,8
M4	54	21	1	1	2	30	0,5	0,0
M4	54	24	2	26	6	10	4,3	0,2
M4	54	32	29	1	2	30	0,5	1,0
M4	54	34	28	0	6	10	0,0	2,8
M4	54	44	3	24	2	30	12,0	0,1
M4	55	23	16	2		0	0,0	0,0
M4	55	31	3	16	1	30	16,0	0,1
M4	55	32	1	21	6	10	3,5	0,1
M4	56	11	0	0	0	0	0,0	0,0

M4	56	12	0	0	0	0	0,0	0,0
M4	56	33	3	19	1	30	19,0	0,1
M4	56	41	2	3		0	0,0	0,0
M4	61	13	21	5	5	10	1,0	2,1
M4	61	21	8	11	3	30	3,7	0,3
M4	61	43	14	2	17	10	0,1	1,4
M4	62	21	15	1	15	10	0,1	1,5
M4	62	31	17	4	11	10	0,4	1,7
M4	63	11	36	0	29	10	0,0	3,6
M4	63	32	0	23	3	30	7,7	0,0
M4	63	44	3	26	2	30	13,0	0,1
M4	64	11	4	28	2	30	14,0	0,1
M4	64	13	4	14	2	30	7,0	0,1
M4	64	22	7	23	4	10	5,8	0,7
M4	64	41	1	24	4	10	6,0	0,1
M4	64	42	5	22	2	30	11,0	0,2
M4	65	11	0	0	0	0	0,0	0,0
M4	65	22	0	0	0	0	0,0	0,0
M4	65	24	29	1	10	10	0,1	2,9
M4	65	44	3	29	8	10	3,6	0,3
M4	65	14	3	16	4	10	4,0	0,3
M4	66	13	0	0	0	0	0,0	0,0
M4	66	21	10	17	8	10	2,1	1,0
M4	66	24	0	30	4	10	7,5	0,0
M4	66	31	0	0	0	0	0,0	0,0
M4	66	32	0	0	0	0	0,0	0,0
M4	66	33	1	20	4	10	5,0	0,1
M4	66	41		1		0	0,0	0,0
M4	67	12	1	20	10	10	2,0	0,1
M4	67	24	0	19	1	30	19,0	0,0
M4	67	32	1	22	4	10	5,5	0,1
M4	68	12	18	1	6	10	0,2	1,8
M4	68	33	0	13	1	30	13,0	0,0
N3	18	14	4	31	20	10	1,6	0,4
N3	28	23	30	2	5	10	0,4	3,0
N3	28	34	1	39	6	10	6,5	0,1
N3	28	43	44	0	6	10	0,0	4,4
N4	11	32	19	1	23	10	0,0	1,9
N4	12	13	15	1	33	5	0,0	3,0
N4	12	21	21	0	34	5	0,0	4,2
N4	12	44	7	13	6	10	2,2	0,7
N4	13	14	1	8	8	10	1,0	0,1
N4	13	21	8	13	1	30	13,0	0,3
N4	13	34	21	14	4	10	3,5	2,1
N4	13	42	9	17	2	30	8,5	0,3
N4	13	44	2	26	7	10	3,7	0,2
N4	14	12	11	15	4	10	3,8	1,1
N4	14	13	10	10	2	30	5,0	0,3
N4	14	23	20	7	4	10	1,8	2,0
N4	14	24	0	27	16	10	1,7	0,0
N4	14	33	15	11	4	10	2,8	1,5
N4	14	42				0	0,0	0,0

N4	14	43	6	12	2	30	6,0	0,2
N4	14	44				0	0,0	0,0
N4	15	13	1	23	2	30	11,5	0,0
N4	15	14				0	0,0	0,0
N4	15	31	2	17	6	10	2,8	0,2
N4	15	32				0	0,0	0,0
N4	15	41	0	0	0	0	0,0	0,0
N4	16	11	0	27	1	30	27,0	0,0
N4	17	14	2	18	7	10	2,6	0,2
N4	17	21	1	25	5	10	5,0	0,1
N4	17	23	23	0	2	30	0,0	0,8
N4	17	24	21	13	15	10	0,9	2,1
N4	17	32	8	11	1	30	11,0	0,3
N4	17	34	4	27	4	10	6,8	0,4
N4	17	44	1	16	2	30	8,0	0,0
N4	18	12	1	17	4	10	4,3	0,1
N4	18	31	0	16	24	10	0,7	0,0
N4	21	12	46	1	25	10	0,0	4,6
N4	21	32		1		0	0,0	0,0
N4	21	33	3	30	4	10	7,5	0,3
N4	21	41	0	0	0	0	0,0	0,0
N4	22	11	0	23	8	10	2,9	0,0
N4	22	13	0	8	12	10	0,7	0,0
N4	22	31	0	32	3	30	10,7	0,0
N4	23	23	0	15	1	30	15,0	0,0
N4	23	34	2	20	7	10	2,9	0,2
N4	24	13	0	22	2	30	11,0	0,0
N4	24	21	0	15	3	30	5,0	0,0
N4	24	22	22	7	12	10	0,6	2,2
N4	27	24	0	22	2	30	11,0	0,0
N4	38	33	1	19	1	30	19,0	0,0
N4	38	44	1	29	3	30	9,7	0,0
N5	11	21	2	33	9	10	3,7	0,2

The number of dips per location are determined by the following assumption:
If the number of mosquitoes per dip is > 0 and < 3 the number of dips taken is 30.
If the number of mosquitoes per dip is ≥ 3 and ≤ 30 the number of dips taken is 10.
If the number of mosquitoes per dip is > 30 the number of dips taken is 5.

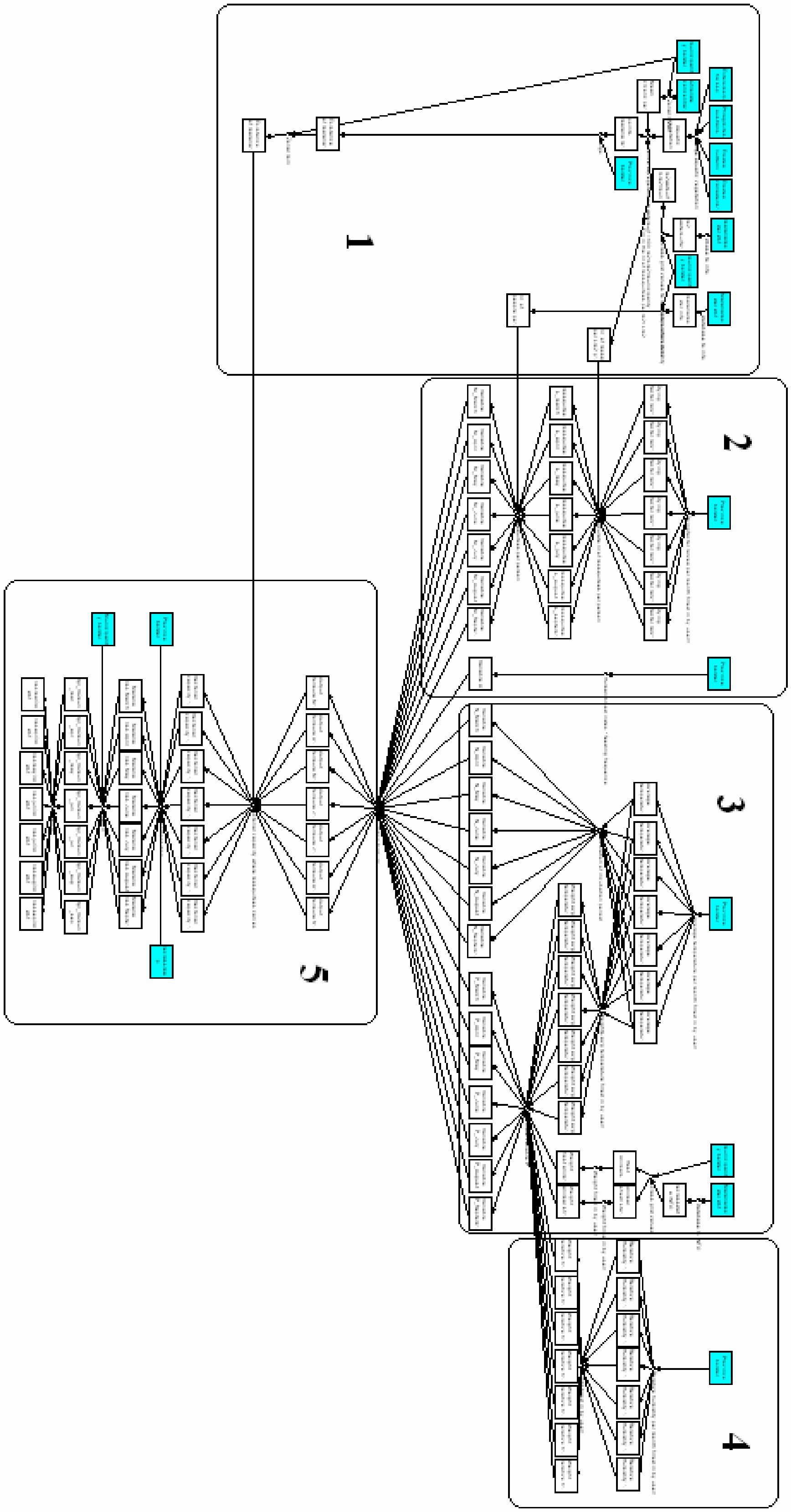
The number of Anopheles atroparvus and Anopheles messeae mosquitoes measured for one location are divided by the number of estimated dip to get the number of mosquitoes per dip.

Maximum and minimum number of mosquitoes per municipality

Municipality	**Estimated nr of larvae per m^2 (An.atroparvus + An. messeae)**	
	min	**max**
Aalsmeer	59	185
Alkmaar	79	533
Amstelveen	44	259
Amsterdam	5	326
Amsterdam	67	237
Andijk	148	1169
Anna Paulowna	96	266

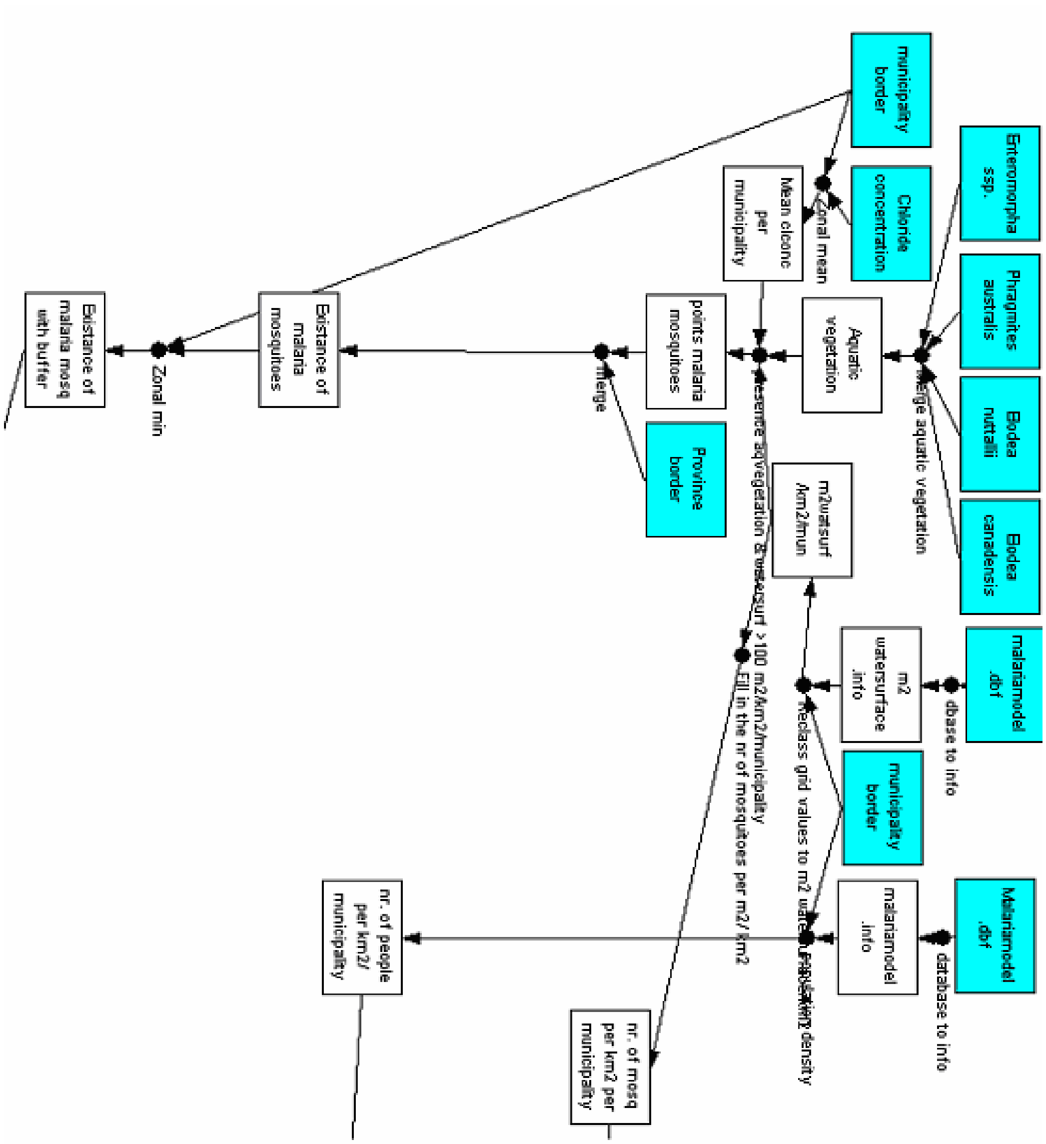
Beemster	25	444
Bennenbroek	-	-
Bergen NH	67	370
Beverwijk	-	377
Blaricum	0	0
Bloemendaal	192	696
Bussum	-	259
Castricum	111	592
Den Helder	30	155
Diemen	-	54
Drechterland	37	237
Edam-Volendam	-	318
Enkhuizen	-	37
Graft-de Rijp	22	533
Haarlem	79	244
Haarlemmerliede	47	155
Haarlemmermeer	37	348
Harenkarspel	42	311
Heemskerk	-	163
Heemstede	-	81
Heerhugowaard	94	548
Heilo	52	266
Hilversum	-	49
Hoorn	-	303
Huizen	-	-
Landsmeer	54	86
Langedijk	44	252
Landsmeer	-	-
Medemblik	74	141
Muiden	-	155
Naarden	32	141
Niedorp	72	533
Noorder-Koggenland	32	318
Obdam	52	488
Oostzaan	0	0
Opmeer	49	533
Ouder-Amstel	59	141
Purmerend	86	303
Schagen	35	303
Schermer	35	533
Stede Broec	-	170
Uitgeest	-	118
Uithoorn	37	207
Velzen	52	59
Venhuizen	42	977
Waterland	39	185
Weesp	47	222
Wevershoof	0	281
Wester-Koggenland	37	488
Wieringen	-	-
Wieringermeer	52	274
Wijdemeren	42	252
Wognum	84	377
Wormerland	15	266
Zaanstad	27	81
Zandvoort	0	0
Zeevang	39	237
Zijpe	27	533

Appendix 4 The ArisFlow model

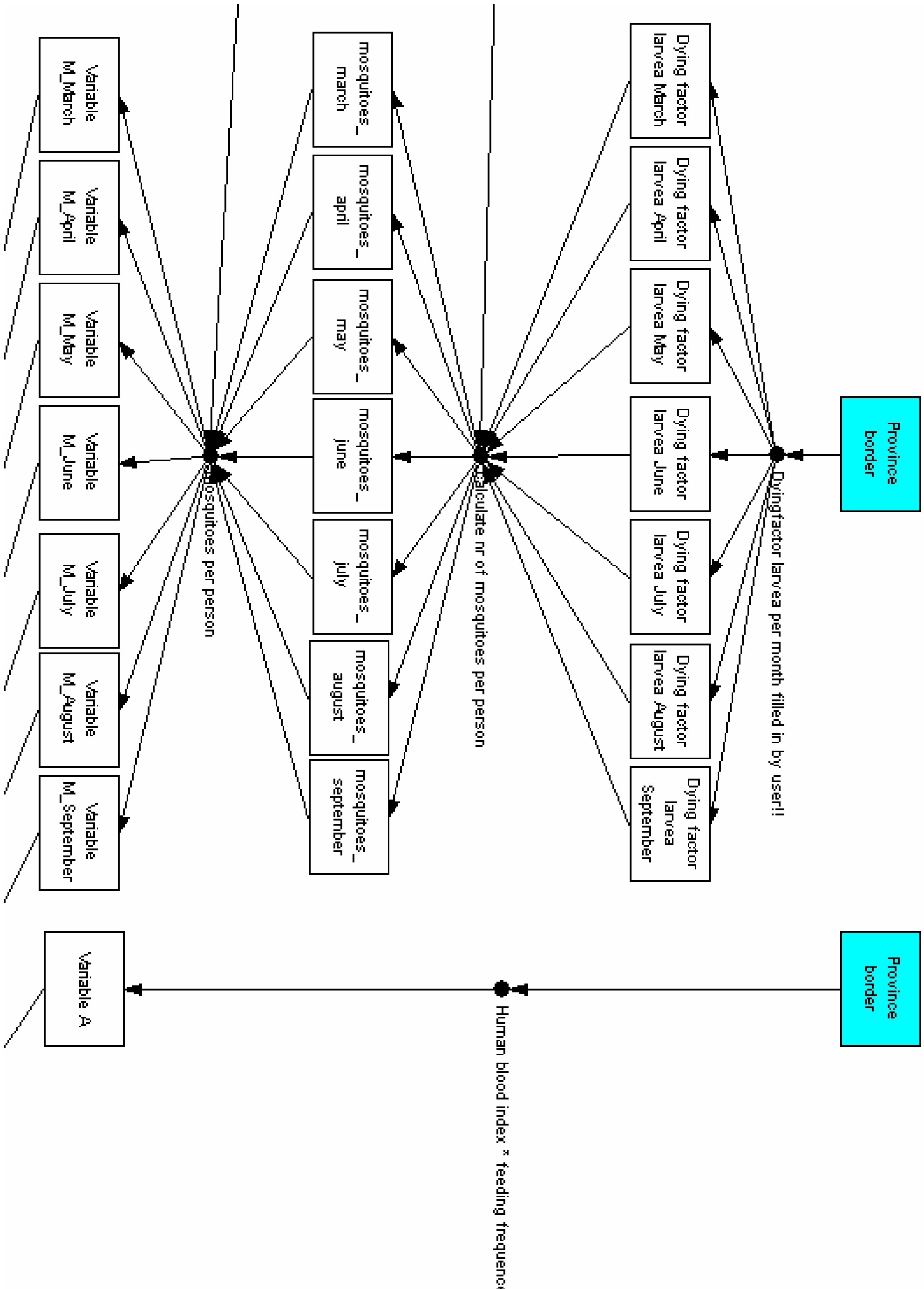


The ArisFlow model displayed in parts

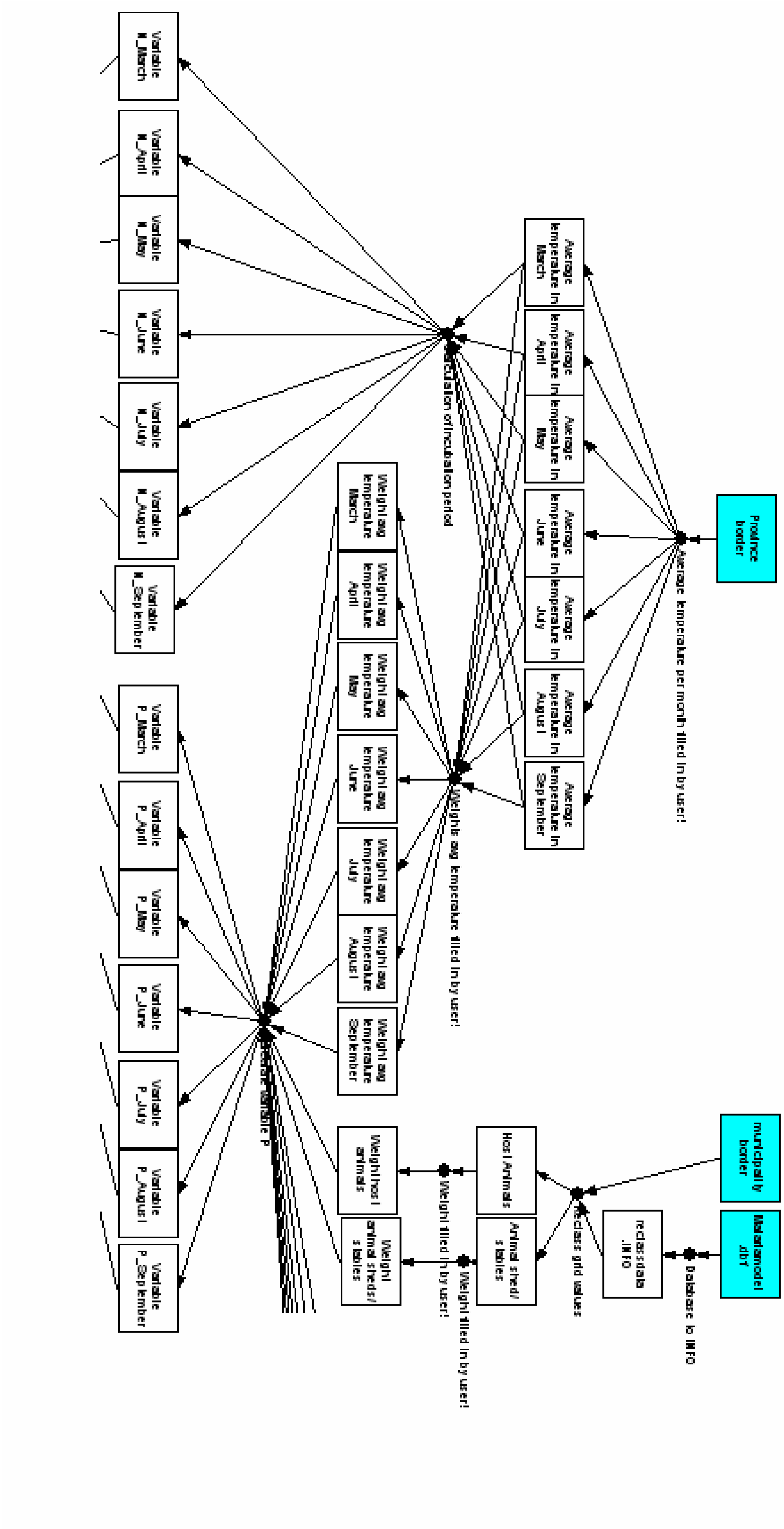
Model-part 1


municipality border
Chloride concentration
Enteromorpha ssp.
Phragmites australis
Elodea nuttallii
Elodea canadensis
Zonal mean
Mean clconc per municipality
Aquatic vegetation
merge aquatic vegetation
points malaria mosquitoes
Province border
merge
Existance of malaria mosquitoes
Zonal min
Existance of malaria mosq with buffer
m2watsurf /km2/mun
malariamodel .dbf
dbase to info
m2 watersurface .info
municipality border
Malariamodel .dbf
database to info
malariamodel .info
Fill in the nr of mosquitoes per m2/km2
nr. of people per km2/ municipality
nr. of mosq per km2 per municipality

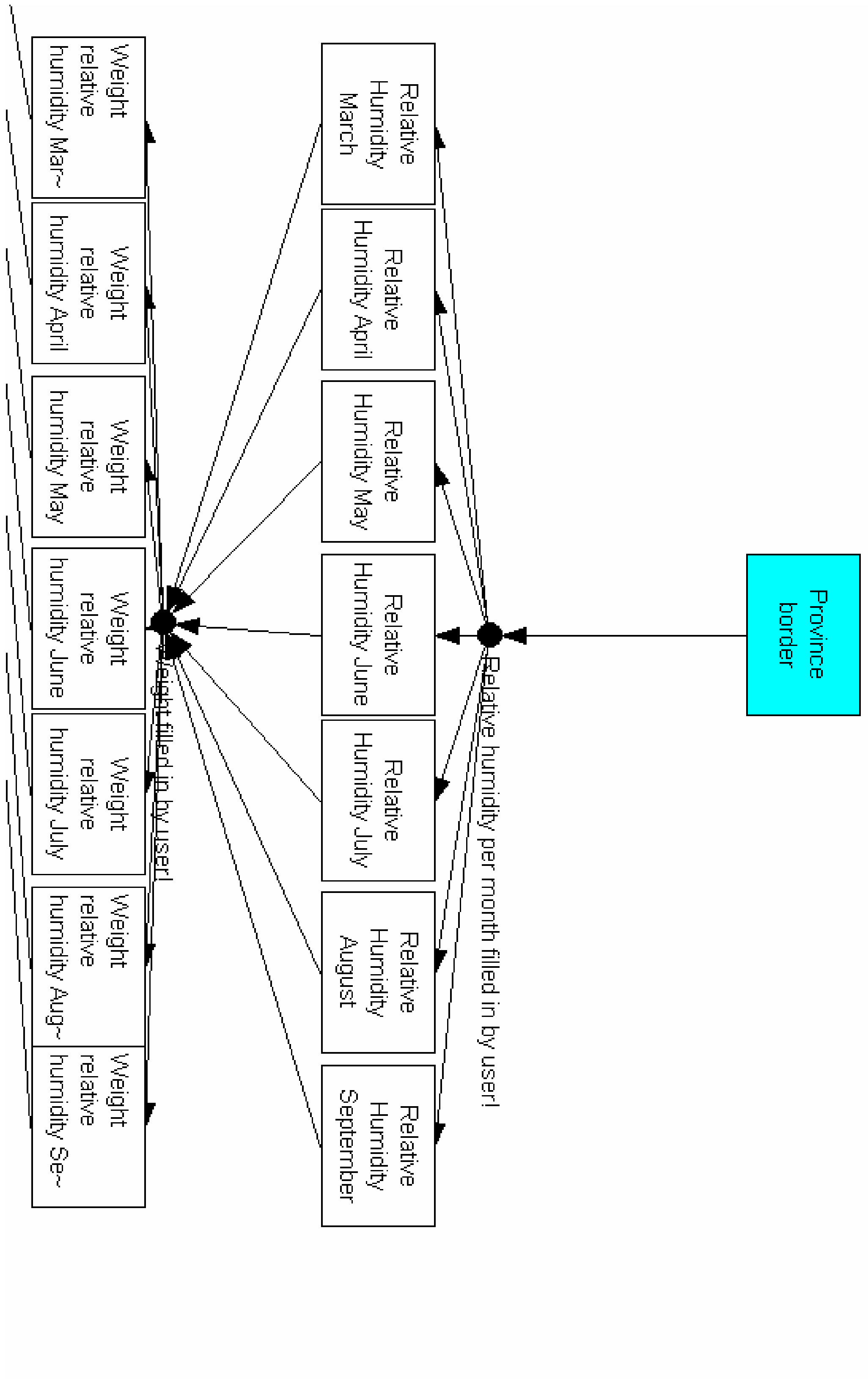
Model-part 2


Province border
Dying factor larvea March
Dying factor larvea April
Dying factor larvea May
Dying factor larvea June
Dying factor larvea July
Dying factor larvea August
Dying factor larvea September
Dyingfactor larvea per month filled in by user!!
mosquitoes_ march
mosquitoes_ april
mosquitoes_ may
mosquitoes_ june
mosquitoes_ july
mosquitoes_ august
mosquitoes_ september
Calculate nr of mosquitoes per person
Variable M_March
Variable M_April
Variable M_May
Variable M_June
Variable M_July
Variable M_August
Variable M_September
mosquitoes per person
Province border
Human blood index * feeding frequence
Variable A

Model-part 3

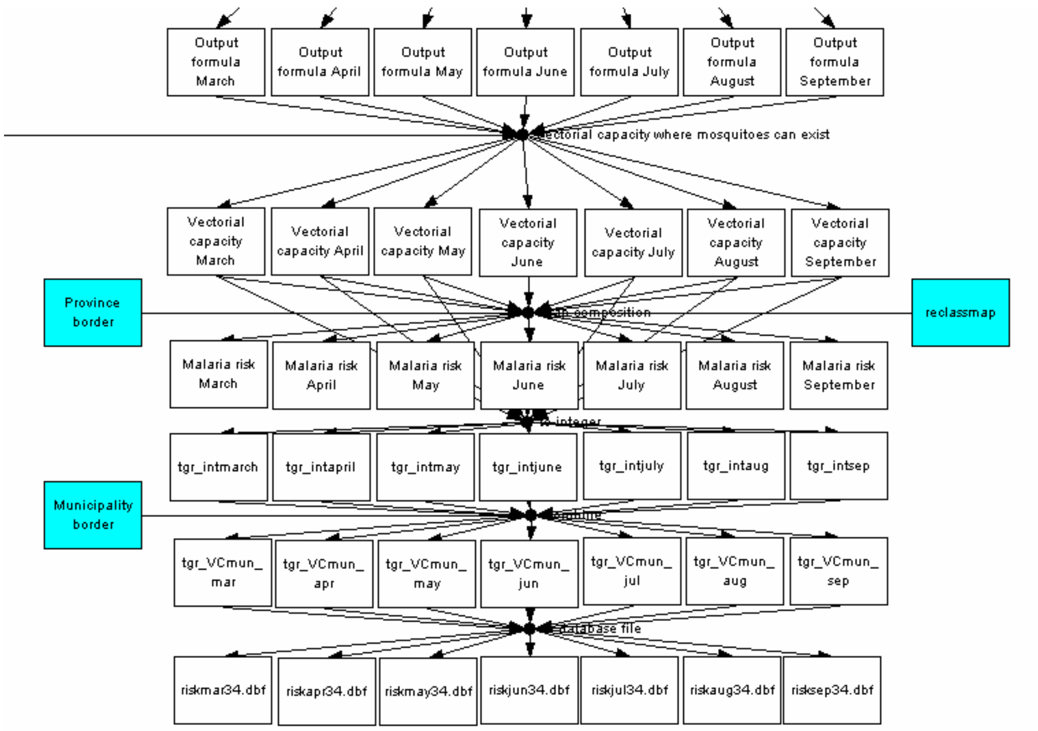

Variable N_March
Variable N_April
Variable N_May
Variable N_June
Variable N_July
Variable N_August
Variable N_September
Variable P_March
Variable P_April
Variable P_May
Variable P_June
Variable P_July
Variable P_August
Variable P_September
Calculation of incubation period
Weight avg temperature March
Weight avg temperature April
Weight avg temperature May
Weight avg temperature June
Weight avg temperature July
Weight avg temperature August
Weight avg temperature September
Weights avg temperature filled in by user!
Average temperature in March
Average temperature in April
Average temperature in May
Average temperature in June
Average temperature in July
Average temperature in August
Average temperature in September
Average temperature per month filled in by user!
Province border
Weight host animals
Weight animal sheds/stables
Weight filled in by user!
Weight filled in by user!
Host Animals
Animal shed/stables
Reclass grid values
reclassdata.INFO
Database to INFO
municipality border
Malariamodel.dbf

Model-part 4



Province border
Relative humidity per month filled in by user!
Relative Humidity March
Relative Humidity April
Relative Humidity May
Relative Humidity June
Relative Humidity July
Relative Humidity August
Relative Humidity September
Weight filled in by user!
Weight relative humidity Mar~
Weight relative humidity April
Weight relative humidity May
Weight relative humidity June
Weight relative humidity July
Weight relative humidity Aug~
Weight relative humidity Se~

Model-part 5



Output formula March
Output formula April
Output formula May
Output formula June
Output formula July
Output formula August
Output formula September
capacity where mosquitoes can exist
Vectorial capacity March
Vectorial capacity April
Vectorial capacity May
Vectorial capacity June
Vectorial capacity July
Vectorial capacity August
Vectorial capacity September
Province border
reclassmap
composition
Malaria risk March
Malaria risk April
Malaria risk May
Malaria risk June
Malaria risk July
Malaria risk August
Malaria risk September
integer
tgr_intmarch
tgr_intapril
tgr_intmay
tgr_intjune
tgr_intjuly
tgr_intaug
tgr_intsep
Municipality border
tgr_VCmun_mar
tgr_VCmun_apr
tgr_VCmun_may
tgr_VCmun_jun
tgr_VCmun_jul
tgr_VCmun_aug
tgr_VCmun_sep
database file
riskmar34.dbf
riskapr34.dbf
riskmay34.dbf
riskjun34.dbf
riskjul34.dbf
riskaug34.dbf
risksep34.dbf

Appendix 5 ArisFlow Commander script

[commentary]
- Do not change section: Variables and section: Server Script.
- Do not change the variable name, only change the values of the parameters in section: Output.
-To run the model change the values of; areakm² (the municipality surface), m²ditch (the m² ditch smaller than 3 meters wide per municipality), hanimal (nr of host animals per municipality), ansheds (nr of animal sheds per municipality) and popmun (nr of inhabitants per municipality), in the input database file. Make sure the same column names are used.
- Fill-in in section: Output the model grids and the model variables.

Description of the variables see below the ArisFlow commander script.
****

```
[variables]
data_action_dir      = C:\margriet\arisflow_scripts_etc\
arisflowdiag         = Themodel1.afd
output_grid_location = C:\margriet\application\
input_grid_location  = C:\margriet\application\
Year
ingrid_Province_border
ingrid_municipality_border
ingrid_Enteromorpha_ssp
ingrid_Phragmites_aus
ingrid_Elodea_nutt
ingrid_Elodea_can
ingrid_CLconc
dbf_file_In
Out_March
Out_April
Out_May
Out_June
Out_July
Out_August
Out_September
dbf_out_March
dbf_out_April
dbf_out_May
dbf_out_June
dbf_out_July
dbf_out_August
dbf_out_September
Min_clconc
Max_clconc
Feeding_frequence
avgtempMarch
avgtempApril
avgtempMay
avgtempJune
avgtempJuly
avgtempAugust
avgtempSeptember
Nrmosquitoes_m2_km2
Human_blood_index
Suitable1_mintemp_mosq
Suitable1_maxtemp_mosq
Weight_suitable1_mosq
Optimum_mintemp_mosq
Optimum_maxtemp_mosq
weight_optimum_mosq
Suitable2_mintemp_mosq
Suitable2_maxtemp_mosq
```

```
Weight_suitable2_mosq
Suitable_minnr_hostanimal
Suitable_maxnr_hostanimal
Weight_suitable_hostanimal
Optimum_minnr_hostanimal
Weight_optimum_hostanimal
Suitable_minnr_stables
Suitable_maxnr_stables
Weight_suitable_stables
Optimum_minnr_stables
Weight_optimum_stables
Minimum_value_rh
Weight_rh
mintemp_inc17
maxtemp_inc17
inc_time17
mintemp_inc16
maxtemp_inc16
inc_time16
mintemp_inc14
maxtemp_inc14
inc_time14
mintemp_inc10
maxtemp_inc10
inc_time10
Relative_humidity_March
Relative_humidity_April
Relative_humidity_May
Relative_humidity_June
Relative_humidity_July
Relative_humidity_August
Relative_humidity_September
nr_raindays_20mm_March
nr_raindays_20mm_April
nr_raindays_20mm_May
nr_raindays_20mm_June
nr_raindays_20mm_July
nr_raindays_20mm_August
nr_raindays_20mm_september

[serverscript]
open(%data_action_dir%%arisflowdiag%)
setDataEntry(province border,%ingrid_Province_border%)
SetDataEntry(municipality border,%ingrid_municipality_border%)
SetDataEntry(Enteromorpha ssp.,%ingrid_Enteromorpha_ssp%)
SetDataEntry(phragmites australis,%ingrid_Phragmites_aus%)
SetDataEntry(elodea nuttallii,%ingrid_Elodea_nutt%)
SetDataEntry(elodea canadensis,%ingrid_Elodea_can%)
SetDataEntry(chloride concentration,%ingrid_CLCONC%)
SetDataEntry(malaria risk march ,%OUT_March%)
SetDataEntry(malaria risk april,%OUT_April%)
SetDataEntry(malaria risk may,%OUT_May%)
SetDataEntry(malaria risk june,%OUT_June%)
SetDataEntry(malaria risk july,%OUT_July%)
SetDataEntry(malaria risk august,%OUT_August%)
SetDataEntry(malaria risk september,%OUT_September%)
SetDataEntry(malariamodel.dbf,%dbf_file_IN%)
SetDataEntry(riskmar34.dbf ,%dbf_out_march%)
SetDataEntry(riskapr34.dbf ,%dbf_out_april%)
SetDataEntry(riskmay34.dbf ,%dbf_out_may%)
SetDataEntry(riskjun34.dbf ,%dbf_out_june%)
```

```
SetDataEntry(riskjul34.dbf ,%dbf_out_july%)
SetDataEntry(riskaug34.dbf ,%dbf_out_august%)
SetDataEntry(risksep34.dbf ,%dbf_out_september%)
SetVariableValue(MIN_CLCONC,%MIN_CLCONC%)
SetVariableValue(MAX_CLCONC,%MAX_CLCONC%)
SetVariableValue(FEEDING_FREQUENCE,%FEEDING_FREQUENCE%)
SetVariableValue(AVGTEMPMARCH,%AVGTEMPMARCH%)
SetVariableValue(AVGTEMPAPRIL,%AVGTEMPAPRIL%)
SetVariableValue(AVGTEMPMAY,%AVGTEMPMAY%)
SetVariableValue(AVGTEMPJUNE,%AVGTEMPJUNE%)
SetVariableValue(AVGTEMPJULY,%AVGTEMPJULY%)
SetVariableValue(AVGTEMPAUGUST,%AVGTEMPAUGUST%)
SetVariableValue(AVGTEMPSEPTEMBER,%AVGTEMPSEPTEMBER%)
setVariableValue(NRMOSQUITOES_M2_KM2,%NRMOSQUITOES_M2_KM2%)
SetVariableValue(HUMAN_BLOOD_INDEX ,%HUMAN_BLOOD_INDEX%)
setVariableValue(suitable1_mintemp_mosq ,%suitable1_mintemp_mosq%)
SetVariableValue(suitable1_maxtemp_mosq ,%suitable1_maxtemp_mosq%)
SetVariableValue(WEIGHT_Suitable1_mosq ,%WEIGHT_Suitable1_mosq%)
SetVariableValue(Optimum_mintemp_mosq ,%optimum_mintemp_mosq%)
SetVariableValue(Optimum_maxtemp_mosq ,%optimum_maxtemp_mosq%)
SetVariableValue(WEIGHT_Optimum_mosq ,%WEIGHT_Optimum_mosq%)
SetVariableValue(suitable2_mintemp_mosq ,%suitable2_mintemp_mosq%)
SetVariableValue(suitable2_maxtemp_mosq ,%suitable2_maxtemp_mosq%)
setVariableValue(WEIGHT_Suitable2_mosq ,%WEIGHT_Suitable2_mosq%)
SetVariableValue(suitable_minnr_hostanimal ,%suitable_minnr_hostanimal%)
SetVariableValue(suitable_maxnr_hostanimal ,%suitable_maxnr_hostanimal%)
SetVariableValue(WEIGHT_Suitable_hostanimal ,%WEIGHT_Suitable_hostanimal%)
SetVariableValue(Optimal_minnr_hostanimal ,%optimum_minnr_hostanimal%)
SetVariableValue(WEIGHT_Optimal_hostanimal ,%WEIGHT_Optimum_hostanimal%)
SetVariableValue(suitable_minnr_stables ,%suitable_minnr_stables%)
SetVariableValue(suitable_maxnr_stables ,%suitable_maxnr_stables%)
setVariableValue(WEIGHT_Suitable_stables ,%WEIGHT_Suitable_stables%)
SetVariableValue(Optimal_minnr_stables ,%optimum_minnr_stables%)
SetVariableValue(WEIGHT_Optimal_stables ,%WEIGHT_Optimum_stables%)
setVariableValue(MINIMUM_VALUE_RH ,%MINIMUM_VALUE_RH%)
setVariableValue(WEIGHT_RH ,%WEIGHT_RH%)
SetVariableValue(Relative_humidity_Mar ,%Relative_humidity_March %)
SetVariableValue(Relative_humidity_Apr ,%Relative_humidity_April%)
SetVariableValue(Relative_humidity_May ,%Relative_humidity_may%)
SetVariableValue(Relative_humidity_Jun ,%Relative_humidity_June%)
SetVariableValue(Relative_humidity_JUl ,%Relative_humidity_July%)
setVariableValue(Relative_humidity_Aug ,%Relative_humidity_August%)
SetVariableValue(Relative_humidity_Sep ,%Relative_humidity_September%)
SetVariableValue(mintemp_inc17,%mintemp_inc17%)
SetVariableValue(maxtemp_inc17,%maxtemp_inc17%)
SetVariableValue(inc_time17,%inc_time17%)
SetVariableValue(mintemp_inc16,%mintemp_inc16%)
SetVariableValue(maxtemp_inc16,%maxtemp_inc16%)
SetVariableValue(inc_time16,%inc_time16%)
SetVariableValue(mintemp_inc14,%mintemp_inc14%)
SetVariableValue(maxtemp_inc14,%maxtemp_inc14%)
SetVariableValue(inc_time14,%inc_time14%)
SetVariableValue(mintemp_inc10,%mintemp_inc10%)
SetVariableValue(maxtemp_inc10,%maxtemp_inc10%)
SetVariableValue(inc_time10,%inc_time10%)
SetVariableValue(nr_raindays_mar,%nr_raindays_20mm_march%)
SetVariableValue(nr_raindays_apr,%nr_raindays_20mm_april%)
SetVariableValue(nr_raindays_may,%nr_raindays_20mm_may%)
SetVariableValue(nr_raindays_jun,%nr_raindays_20mm_june%)
SetVariableValue(nr_raindays_jul,%nr_raindays_20mm_july%)
SetVariableValue(nr_raindays_aug,%nr_raindays_20mm_august%)
```

```
SetVariableValue(nr_raindays_sep,%nr_raindays_20mm_september%)
SetVariableValue (year,%year%)
Executeall

[output]
Year                              = 1934
ingrid_Province_border            = provgrens
ingrid_municipality_border        = gemeenten
ingrid_Enteromorpha_ssp           = enteromorph34
ingrid_Phragmites_aus             = phragau34
ingrid_Elodea_nutt                = elodeanut34
ingrid_Elodea_can                 = elodeacan34
ingrid_CLCONC                     = clconc34

dbf_file_In                       = malariamodel34.dbf

Out_March                         = Risk_march34
Out_April                         = Risk_april34
Out_May                           = Risk_may34
Out_June                          = Risk_june34
Out_July                          = Risk_july34
Out_August                        = Risk_aug34
Out_September                     = Risk_sept34

dbf_out_March                      = riskmar34.dbf
dbf_out_April                      = riskapr34.dbf
dbf_out_May                        = riskmay34.dbf
dbf_out_June                       = riskjun34.dbf
dbf_out_July                       = riskjul34.dbf
dbf_out_August                     = riskaug34.dbf
dbf_out_September                  = risksep34.dbf

min_clconc                        =  700
max_clconc                        = 2500

avgtempMarch                      = 4.8
avgtempApril                      = 10.3
avgtempMay                        = 12.1
avgtempJune                       = 15.9
avgtempJuly                       = 17.7
avgtempAugust                     = 16.2
avgtempSeptember                          = 16

Suitable1_mintemp_mosq            = 10
Suitable1_maxtemp_mosq            = 20
Weight_suitable1_mosq             = 0.98
Optimum_mintemp_mosq              = 21
Optimum_maxtemp_mosq              = 30
Weight_optimum_mosq               = 0.98
Suitable2_mintemp_mosq            = 31
Suitable2_maxtemp_mosq            = 40
Weight_suitable2_mosq             = 0.98

suitable_minnr_hostanimal         = 1
suitable_maxnr_hostanimal         = 10
weight_suitable_hostanimal        = 0.94
optimum_minnr_hostanimal          = 11
weight_optimum_hostanimal         = 0.94

suitable_minnr_stables            = 1
suitable_maxnr_stables            = 10
weight_suitable_stables           = 0.94
optimum_minnr_stables             = 11
```

weight_optimum_stables = 0.94

Nrmosquitoes_m2_km2 = 500
Human_blood_index = 0.125
Feeding_frequence = 1

Relative_humidity_March = 60
Relative_humidity_April = 60
Relative_humidity_May = 60
Relative_humidity_June = 60
Relative_humidity_July = 60
Relative_humidity_August = 60
Relative_humidity_September = 60
Minimum_value_rh = 60
Weight_rh = 0.98

mintemp_inc17 = 15
maxtemp_inc17 = 19
inc_time17 = 17
mintemp_inc16 = 19
maxtemp_inc16 = 21
inc_time16 = 16
mintemp_inc14 = 21
maxtemp_inc14 = 25
inc_time14 = 14
mintemp_inc10 = 25
maxtemp_inc10 = 28
inc_time10 = 10

nr_raindays_20mm_march = 0
nr_raindays_20mm_april = 0
nr_raindays_20mm_may = 1
nr_raindays_20mm_June = 0
nr_raindays_20mm_July = 0
nr_raindays_20mm_August = 0
nr_raindays_20mm_September = 0

Description of the variables:

Year	= The year of interest.
ingrid_Province_border	= Grid with the province borders of the research area.
ingrid_municipality_border	= Grid with the municipality borders of the research area.
ingrid_Enteromorpha_ssp	= Grid with vegetation type Enteromorpha ssp in the research area.
ingrid_Phragmites_aus	= Grid with vegetation type Phragmites australis in the research area.
ingrid_Elodea_nutt	= Grid with vegetation type Elodea nuttallii in the research area.
ingrid_Elodea_can	= Grid with vegetation type Elodea canadensis in the research area.
Ingrid_Clconc	= Grid with the chloride concentrations in the research area.
dbf_file_In	= The input database file with the colums mentioned in section commentary. Save database file with dbf(IV) extension.
Out_March	= Output grid name for the month March.
Out_April	= Output grid name for the month April.
Out_May	= Output grid name for the month May.
Out_June	= Output grid name for the month June.
Out_July	= Output grid name for the month July.
Out_August	= Output grid name for the month August.
Out_September	= Output grid name for the month September.
min_clconc	= Minimum chloride concentration at which mosquito larvae exist.
max_clconc	= Maximum chloride concentration at which mosquito larvae exist.
avgtempMarch	= Average temperature in March.
avgtempApril	= Average temperature in April.
avgtempMay	= Average temperature in May.
avgtempJune	= Average temperature in June.
avgtempJuly	= Average temperature in July.
avgtempAugust	= Average temperature in August.
avgtempSeptember	= Average temperature in September.
Suitable1_mintemp_mosq	= Minimum temperature of the lower Suitable range for mosquitoes to exist.
Suitable1_maxtemp_mosq	= Maximum temperature of the lower Suitable range for mosquitoes to exist.
Weight_suitable1_mosq	= Weight of Suitable temperature range for mosquitoes[3].
Optimum_mintemp_mosq	= Minimum temperature of the Optimal range for mosquitoes to exist.
Optimum_maxtemp_mosq	= Maximum temperature of the Optimal range for mosquitoes to exist.
Weight_optimum_mosq	= Weight of Optimal temperature range for mosquitoes.
Suitable2_mintemp_mosq	= Minimum temperature of the higher Suitable range for mosquitoes to exist.
Suitable2_maxtemp_mosq	= Maximum temperature of the higher Suitable range for mosquitoes to exist.
Weight_suitable2_mosq	= Weight of Suitable temperature range for mosquitoes.
Suitable_minnr_hostanimal	= Minimum nr of host animals per km^2 per municipality for Suitable living conditions of the mosquito.
Suitable_maxnr_hostanimal	= Maximum nr of host animals per km^2 per municipality for Suitable living conditions of the mosquito.
Weight_suitable_hostanimal	= Weight for a Suitable living conditions of the mosquitoes due to nr of host animals.
Optimum_minnr_hostanimal	= Minimum nr of host animals per km^2 per municipality for Optimal living conditions of the mosquito.
Weight_optimum_hostanimal	= Weight for a Optimal living conditions of the mosquitoes due to nr of host animals.

[3] Weights for temperatures ranges at which mosquito can exist, weights for the number of host animals, weights for the number of animal sheds /stables and weights for the relative humidity are multiplied and determine factor **p**: the daily mosquito survival rate.

Suitable_minnr_stables	= Minimum nr of sheds/ stables per km² per municipality for Suitable living conditions of the mosquito.
Suitable_maxnr_stables	= Maximum nr of sheds/ stables per km² per municipality for Suitable living conditions of the mosquito.
Weight_suitable_stables	= Weight for a Suitable living conditions of the mosquitoes due to nr of sheds/ stables.
Optimum_minnr_stables	= Minimum nr of sheds/ stables per km² per municipality for Optimal living conditions of the mosquito.
Weight_optimum_stables	= Weight for a Suitable living conditions of the mosquitoes due to nr of sheds/ stables.
Relative_humidity_March	= Relative humidity in March.
Relative_humidity_April	= Relative humidity in April.
Relative_humidity_May	= Relative humidity in May.
Relative_humidity_June	= Relative humidity in June.
Relative_humidity_July	= Relative humidity in July.
Relative_humidity_August	= Relative humidity in August.
Relative_humidity_September	= Relative humidity in September.
Minimum_value_rh	= Minimum value for the relative humidity at which the mosquitoes exist.
Weight_rh	= Weight of the relative humidity.
Nrmosquitoes_m2_km2	= Number of mosquitoes per m² per km² per municipality.
Human_blood_index	= Human Blood Index of the mosquito.
Feeding_frequence	= Feeding frequency of the mosquito.
mintemp_inc17	= Minimum temperature for incubation time is 17 days.
maxtemp_inc17	= Maximum temperature for incubation time is 17 days.
inc_time17	= Extrinsic incubation time at temperature range defined above. Standard fill in 17, if else is wanted fill in other value.
mintemp_inc16	= Minimum temperature for incubation time is 16 days.
maxtemp_inc16	= Maximum temperature for incubation time is 16 days.
inc_time16	= Extrinsic incubation time at temperature range defined above. Standard fill in 16, if else is wanted fill in other value.
mintemp_inc14	= Minimum temperature for incubation time is 14 days.
maxtemp_inc14	= Maximum temperature for incubation time is 14 days.
inc_time14	= Extrinsic incubation time at temperature range defined above. Standard fill in 14, if else is wanted fill in other value.
mintemp_inc10	= Minimum temperature for incubation time is 10 days.
maxtemp_inc10	= Maximum temperature for incubation time is 10 days.
inc_time10	= Extrinsic incubation time at temperature range defined above. Standard fill in 10, if else is wanted fill in other value.
nr_raindays_20mm_march	= The nr. of days in the month March that rainfall exceeds 20 mm/day.
nr_raindays_20mm_april	= The nr. of days in the month March that rainfall exceeds 20 mm/day.
nr_raindays_20mm_may	= The nr. of days in the month March that rainfall exceeds 20 mm/day.
nr_raindays_20mm_June	= The nr. of days in the month March that rainfall exceeds 20 mm/day.
nr_raindays_20mm_July	= The nr. of days in the month March that rainfall exceeds 20 mm/day.
nr_raindays_20mm_August	= The nr. of days in the month March that rainfall exceeds 20 mm/day.
nr_raindays_20mm_September	= The nr. of days in the month March that rainfall exceeds 20 mm/day.

Appendix 6 Municipalities of 2003 per malaria district

District number	Municipalities of 2003
1	▪ Anna Paulowna ▪ Den Helder ▪ Wieringen ▪ Zijpe
2	▪ Niedorp ▪ Schagen
3	▪ Bergen (NH) ▪ Harenkarspel ▪ Heiloo
4	▪ Heerhugowaard ▪ Langedijk ▪ Obdam ▪ Opmeer
5	▪ Andijk ▪ Drechterland ▪ Medemblik ▪ Noorder-Koggenland ▪ Venhuizen ▪ Wevershoof ▪ Wognum
6	▪ Enkhuizen ▪ Hoorn ▪ Stede Broec ▪ Wester-Koggenland
7	▪ Alkmaar ▪ Castricum ▪ Graft-de Rijp ▪ Schermer ▪ Uitgeest
8	▪ Beemster ▪ Edam-Volendam ▪ Purmerend ▪ Waterland ▪ Zeevang
9	▪ Landsmeer ▪ Oostzaan ▪ Wormerland ▪ Zaanstad
10	▪ Aalsmeer ▪ Bennebroek ▪ Beverwijk ▪ Bloemendaal ▪ Haarlem ▪ Haarlemmerliede CA ▪ Haarlemermeer ▪ Heemskerk ▪ Heemstede ▪ Velsen ▪ Zandvoort
11	▪ Amsterdam-Zuid ▪ Diemen ▪ Muiden ▪ Naarden ▪ Ouder-Amstel ▪ Uithoorn ▪ Weesp

	▪ Wijdemeren
NO DATA	▪ Amsterdam ▪ Blaricum ▪ Bussum ▪ Hilversum ▪ Huizen ▪ Laren ▪ Wieringermeer

Appendix 7 Results

This appendix shows the malaria cases for the years 1934 and 2003 at different values for the feeding frequency and the daily mosquito survival rate. Some tests are done when using the maximum temperature in stead of the average temperature as input and when using a high Human Blood Index. The months which give an output are displayed. The months that do not give output had temperatures lower than 15°C, the assumption is that Plasmodium vivax can not develop under this circumstance.

Initial values are used: Feeding frequency = 0,20, Human Blood Index = 0,05, the daily mosquito survival rate = 0,85 and the average temperature is used.

	1934				2003		
Municipality	June	July	August	September	June	July	August
WIERINGEN	0	0	0	0	1	1	1
DEN HELDER	0	0	0	0	0	0	0
WIERINGERMEER	5	1	1	5	6	6	7
ANNA PAULOWNA	12	3	3	12	14	14	17
ZIJPE	13	4	4	13	7	7	9
SCHAGEN	7	2	2	7	6	6	8
NIEDORP	10	3	3	10	5	5	6
HARENKARSPEL	4	1	1	4	4	4	5
MEDEMBLIK	0	0	0	0	0	0	0
NOORDER-KOGGENLAND	9	2	2	9	9	9	11
BERGEN NH	3	1	1	3	2	2	3
WERVERSHOOF	32	9	9	32	18	18	21
OPMEER	4	1	1	4	0	0	0
ANDIJK	1	0	0	1	0	0	0
ENKHUIZEN	0	0	0	0	0	0	0
LANGEDIJK	1	0	0	1	2	2	2
HEERHUGOWAARD	10	3	3	10	5	5	7
STEDE BROEC	0	0	0	0	0	0	0
DRECHTERLAND	2	0	0	2	0	0	0
WOGNUM	8	2	2	8	4	4	5
OBDAM	10	3	3	10	8	8	9
VENHUIZEN	36	11	11	36	11	11	13
ALKMAAR	0	0	0	0	0	0	0
HOORN	1	0	0	1	0	0	0
WESTER-KOGGENLAND	11	3	3	11	7	7	8
SCHERMER	21	6	6	21	12	12	14
HEILOO	3	0	0	3	3	3	4
BEEMSTER	13	3	3	13	8	8	10
ZEEVANG	6	1	1	6	7	7	8
CASTRICUM	6	2	2	6	0	0	0
GRAFT-DE RIJP	9	2	2	9	5	5	6
UITGEEST	1	0	0	1	4	4	4
WORMERLAND	5	1	1	5	5	5	7
HEEMSKERK	3	1	1	3	7	7	8
PURMEREND	6	1	1	6	0	0	0
EDAM-VOLENDAM	2	0	0	2	2	2	2
ZAANSTAD	0	0	0	0	0	0	0
BEVERWIJK	1	0	0	1	0	0	0
WATERLAND	2	0	0	2	4	4	4
VELSEN	0	0	0	0	0	0	0
LANDSMEER	3	1	1	3	12	12	15
OOSTZAAN	0	0	0	0	3	3	3
BLOEMENDAAL	0	0	0	0	0	0	0
HAARLEMMERLIEDE CA	5	1	1	5	0	0	0

AMSTERDAM	0	0	0	0	0	0	0
HAARLEM	0	0	0	0	0	0	0
ZANDVOORT	0	0	0	0	0	0	0
HAARLEMMERMEER	11	3	3	11	0	0	0
HEEMSTEDE	0	0	0	0	0	0	0
DIEMEN	0	0	0	0	0	0	0
MUIDEN	0	0	0	0	0	0	0
OUDER-AMSTEL	2	0	0	2	0	0	0
AMSTERDAM	0	0	0	0	0	0	0
AMSTELVEEN	3	0	0	3	0	0	0
BENNEBROEK	0	0	0	0	0	0	0
NAARDEN	0	0	0	0	0	0	0
WEESP	0	0	0	0	0	0	0
HUIZEN	0	0	0	0	0	0	0
AALSMEER	0	0	0	0	0	0	0
BLARICUM	0	0	0	0	0	0	0
HILVERSUM	0	0	0	0	0	0	0
WIJDEMEREN	17	5	5	17	0	0	0
BUSSUM	0	0	0	0	0	0	0
LAREN	0	0	0	0	0	0	0
UITHOORN	8	2	2	8	0	0	0
Total	**306**	**78**	**78**	**306**	**181**	**181**	**217**

Feeding frequency = 0,30, Human Blood Index = 0,05, the daily mosquito survival rate = 0,79 and the average temperature is used.

	1934				2003		
Municipality	**June**	**July**	**August**	**September**	**June**	**July**	**August**
WIERINGEN	0	0	0	0	0	0	0
DEN HELDER	0	0	0	0	0	0	0
WIERINGERMEER	2	0	0	2	2	2	3
ANNA PAULOWNA	5	1	1	5	6	6	8
ZIJPE	6	1	1	6	3	3	4
SCHAGEN	3	0	0	3	3	3	3
NIEDORP	4	1	1	4	2	2	3
HARENKARSPEL	2	0	0	2	1	1	2
MEDEMBLIK	0	0	0	0	0	0	0
NOORDER-KOGGENLAND	4	1	1	4	4	4	5
BERGEN NH	1	0	0	1	1	1	1
WERVERSHOOF	14	4	4	14	8	8	10
OPMEER	1	0	0	1	0	0	0
ANDIJK	0	0	0	0	0	0	0
ENKHUIZEN	0	0	0	0	0	0	0
LANGEDIJK	0	0	0	0	0	0	1
HEERHUGOWAARD	4	1	1	4	2	2	3
STEDE BROEC	0	0	0	0	0	0	0
DRECHTERLAND	1	0	0	1	0	0	0
WOGNUM	3	1	1	3	2	2	2
OBDAM	4	1	1	4	3	3	4
VENHUIZEN	16	4	4	16	5	5	6
ALKMAAR	0	0	0	0	0	0	0
HOORN	0	0	0	0	0	0	0
WESTER-KOGGENLAND	5	1	1	5	3	3	4
SCHERMER	9	2	2	9	5	5	6
HEILOO	1	0	0	1	1	1	2
BEEMSTER	5	1	1	5	3	3	4
ZEEVANG	2	0	0	2	3	3	4
CASTRICUM	3	0	0	3	0	0	0

GRAFT-DE RIJP	4	1	1	4	2	2	3
UITGEEST	0	0	0	0	1	1	2
WORMERLAND	2	0	0	2	2	2	3
HEEMSKERK	1	0	0	1	3	3	4
PURMEREND	2	0	0	2	0	0	0
EDAM-VOLENDAM	1	0	0	1	0	0	1
ZAANSTAD	0	0	0	0	0	0	0
BEVERWIJK	0	0	0	0	0	0	0
WATERLAND	1	0	0	1	1	1	2
VELSEN	0	0	0	0	0	0	0
LANDSMEER	1	0	0	1	5	5	7
OOSTZAAN	0	0	0	0	1	1	1
BLOEMENDAAL	0	0	0	0	0	0	0
HAARLEMMERLIEDE CA	2	0	0	2	0	0	0
AMSTERDAM	0	0	0	0	0	0	0
HAARLEM	0	0	0	0	0	0	0
ZANDVOORT	0	0	0	0	0	0	0
HAARLEMMERMEER	5	1	1	5	0	0	0
HEEMSTEDE	0	0	0	0	0	0	0
DIEMEN	0	0	0	0	0	0	0
MUIDEN	0	0	0	0	0	0	0
OUDER-AMSTEL	1	0	0	1	0	0	0
AMSTERDAM	0	0	0	0	0	0	0
AMSTELVEEN	1	0	0	1	0	0	0
BENNEBROEK	0	0	0	0	0	0	0
NAARDEN	0	0	0	0	0	0	0
WEESP	0	0	0	0	0	0	0
HUIZEN	0	0	0	0	0	0	0
AALSMEER	0	0	0	0	0	0	0
BLARICUM	0	0	0	0	0	0	0
HILVERSUM	0	0	0	0	0	0	0
WIJDEMEREN	7	2	2	7	0	0	0
BUSSUM	0	0	0	0	0	0	0
LAREN	0	0	0	0	0	0	0
UITHOORN	3	1	1	3	0	0	0
Total	**126**	**24**	**24**	**126**	**72**	**72**	**98**

Feeding frequency = 0,20, Human Blood Index = 0,05, the daily mosquito survival rate = 0,79 and the maximum temperature is used.

	1934						2003				
Municipality	April	May	June	July	August	September	April	May	June	July	August
WIERINGEN	0	0	0	0	0	0	0	0	0	0	1
DEN HELDER	0	0	0	0	0	0	0	0	0	0	0
WIERINGERMEER	1	0	2	0	0	2	1	0	2	2	6
ANNA PAULOWNA	2	0	5	1	1	5	2	0	5	5	14
ZIJPE	2	0	5	1	1	5	1	0	3	3	8
SCHAGEN	1	0	2	0	0	2	1	0	2	2	7
NIEDORP	1	0	4	1	1	4	1	0	2	2	5
HARENKARSPEL	0	0	1	0	0	1	0	0	1	1	4
MEDEMBLIK	0	0	0	0	0	0	0	0	0	0	0
NOORDER-KOGGENLAND	1	0	3	1	1	3	1	0	3	3	9
BERGEN NH	0	0	1	0	0	1	0	0	1	1	2
WERVERSHOOF	6	1	13	3	3	13	3	1	7	7	18
OPMEER	0	0	1	0	0	1	0	0	0	0	0
ANDIJK	0	0	0	0	0	0	0	0	0	0	0
ENKHUIZEN	0	0	0	0	0	0	0	0	0	0	0
LANGEDIJK	0	0	0	0	0	0	0	0	0	0	2

HEERHUGOWAARD	2	0	4	1	1	4	1	0	2	2	6
STEDE BROEC	0	0	0	0	0	0	0	0	0	0	0
DRECHTERLAND	0	0	1	0	0	1	0	0	0	0	0
WOGNUM	1	0	3	0	0	3	0	0	1	1	5
OBDAM	2	0	4	1	1	4	1	0	3	3	8
VENHUIZEN	7	2	14	4	4	14	2	0	4	4	11
ALKMAAR	0	0	0	0	0	0	0	0	0	0	0
HOORN	0	0	0	0	0	0	0	0	0	0	0
WESTER-KOGGENLAND	2	0	4	1	1	4	1	0	2	2	7
SCHERMER	4	1	8	2	2	8	2	0	4	4	12
HEILOO	0	0	1	0	0	1	0	0	1	1	3
BEEMSTER	2	0	5	1	1	5	1	0	3	3	9
ZEEVANG	1	0	2	0	0	2	1	0	3	3	7
CASTRICUM	1	0	2	0	0	2	0	0	0	0	0
GRAFT-DE RIJP	1	0	3	1	1	3	1	0	2	2	5
UITGEEST	0	0	0	0	0	0	0	0	1	1	4
WORMERLAND	1	0	2	0	0	2	1	0	2	2	6
HEEMSKERK	0	0	1	0	0	1	1	0	2	2	7
PURMEREND	1	0	2	0	0	2	0	0	0	0	0
EDAM-VOLENDAM	0	0	0	0	0	0	0	0	0	0	2
ZAANSTAD	0	0	0	0	0	0	0	0	0	0	0
BEVERWIJK	0	0	0	0	0	0	0	0	0	0	0
WATERLAND	0	0	1	0	0	1	0	0	1	1	4
VELSEN	0	0	0	0	0	0	0	0	0	0	0
LANDSMEER	0	0	1	0	0	1	2	0	5	5	13
OOSTZAAN	0	0	0	0	0	0	0	0	1	1	3
BLOEMENDAAL	0	0	0	0	0	0	0	0	0	0	0
HAARLEMMERLIEDE CA	1	0	2	0	0	2	0	0	0	0	0
AMSTERDAM	0	0	0	0	0	0	0	0	0	0	0
HAARLEM	0	0	0	0	0	0	0	0	0	0	0
ZANDVOORT	0	0	0	0	0	0	0	0	0	0	0
HAARLEMMERMEER	2	0	4	1	1	4	0	0	0	0	0
HEEMSTEDE	0	0	0	0	0	0	0	0	0	0	0
DIEMEN	0	0	0	0	0	0	0	0	0	0	0
MUIDEN	0	0	0	0	0	0	0	0	0	0	0
OUDER-AMSTEL	0	0	0	0	0	0	0	0	0	0	0
AMSTERDAM	0	0	0	0	0	0	0	0	0	0	0
AMSTELVEEN	0	0	1	0	0	1	0	0	0	0	0
BENNEBROEK	0	0	0	0	0	0	0	0	0	0	0
NAARDEN	0	0	0	0	0	0	0	0	0	0	0
WEESP	0	0	0	0	0	0	0	0	0	0	0
HUIZEN	0	0	0	0	0	0	0	0	0	0	0
AALSMEER	0	0	0	0	0	0	0	0	0	0	0
BLARICUM	0	0	0	0	0	0	0	0	0	0	0
HILVERSUM	0	0	0	0	0	0	0	0	0	0	0
WIJDEMEREN	3	1	7	2	2	7	0	0	0	0	0
BUSSUM	0	0	0	0	0	0	0	0	0	0	0
LAREN	0	0	0	0	0	0	0	0	0	0	0
UITHOORN	1	0	3	1	1	3	0	0	0	0	0
Total	**46**	**5**	**112**	**22**	**22**	**112**	**24**	**1**	**63**	**63**	**188**

Feeding frequency = 0,30, Human Blood Index = 0,50, the daily mosquito survival rate = 0,79 and the average temperature is used.

	1934	2003

Municipality	June	July	August	September	June	July	August
WIERINGEN	0	0	0	0	73	73	92
DEN HELDER	6	1	1	6	12	12	16
WIERINGERMEER	264	79	79	264	290	290	367
ANNA PAULOWNA	573	171	171	573	646	646	818
ZIJPE	622	186	186	622	350	350	443
SCHAGEN	313	94	94	313	310	310	393
NIEDORP	449	134	134	449	253	253	320
HARENKARSPEL	200	60	60	200	193	193	244
MEDEMBLIK	15	4	4	15	0	0	0
NOORDER-KOGGENLAND	443	132	132	443	418	418	529
BERGEN NH	156	47	47	156	127	127	161
WERVERSHOOF	1444	433	433	1444	813	813	1029
OPMEER	179	53	53	179	0	0	0
ANDIJK	85	25	25	85	0	0	0
ENKHUIZEN	2	0	0	2	16	16	20
LANGEDIJK	75	22	22	75	89	89	113
HEERHUGOWAARD	489	146	146	489	267	267	338
STEDE BROEC	16	4	4	16	28	28	35
DRECHTERLAND	121	36	36	121	0	0	0
WOGNUM	359	107	107	359	221	221	279
OBDAM	472	141	141	472	375	375	475
VENHUIZEN	1645	493	493	1645	505	505	639
ALKMAAR	18	5	5	18	10	10	13
HOORN	56	17	17	56	0	0	0
WESTER-KOGGENLAND	516	154	154	516	317	317	402
SCHERMER	971	291	291	971	546	546	692
HEILOO	147	44	44	147	166	166	211
BEEMSTER	584	175	175	584	394	394	499
ZEEVANG	268	80	80	268	339	339	430
CASTRICUM	312	93	93	312	0	0	0
GRAFT-DE RIJP	434	130	130	434	244	244	309
UITGEEST	70	21	21	70	179	179	227
WORMERLAND	237	71	71	237	267	267	338
HEEMSKERK	171	51	51	171	316	316	400
PURMEREND	289	86	86	289	0	0	0
EDAM-VOLENDAM	100	30	30	100	95	95	120
ZAANSTAD	9	2	2	9	34	34	43
BEVERWIJK	47	14	14	47	0	0	0
WATERLAND	113	34	34	113	184	184	233
VELSEN	2	0	0	2	0	0	0
LANDSMEER	166	49	49	166	579	579	733
OOSTZAAN	0	0	0	0	142	142	180
BLOEMENDAAL	14	4	4	14	0	0	0
HAARLEMMERLIEDE CA	263	79	79	263	0	0	0
AMSTERDAM	4	1	1	4	0	0	0
HAARLEM	7	2	2	7	0	0	0
ZANDVOORT	0	0	0	0	0	0	0
HAARLEMMERMEER	529	158	158	529	0	0	0
HEEMSTEDE	2	0	0	2	0	0	0
DIEMEN	16	4	4	16	0	0	0
MUIDEN	0	0	0	0	0	0	0

OUDER-AMSTEL	101	30	30	101	0	0	0
AMSTERDAM	0	0	0	0	0	0	0
AMSTELVEEN	141	42	42	141	0	0	0
BENNEBROEK	6	2	2	6	0	0	0
NAARDEN	28	8	8	28	0	0	0
WEESP	13	4	4	13	0	0	0
HUIZEN	0	0	0	0	0	0	0
AALSMEER	35	10	10	35	0	0	0
BLARICUM	0	0	0	0	0	0	0
HILVERSUM	1	0	0	1	0	0	0
WIJDEMEREN	786	235	235	786	0	0	0
BUSSUM	0	0	0	0	0	0	0
LAREN	0	0	0	0	0	0	0
UITHOORN	394	118	118	394	0	0	0
Total	**14778**	**4412**	**4412**	**14778**	**8798**	**8798**	**11141**