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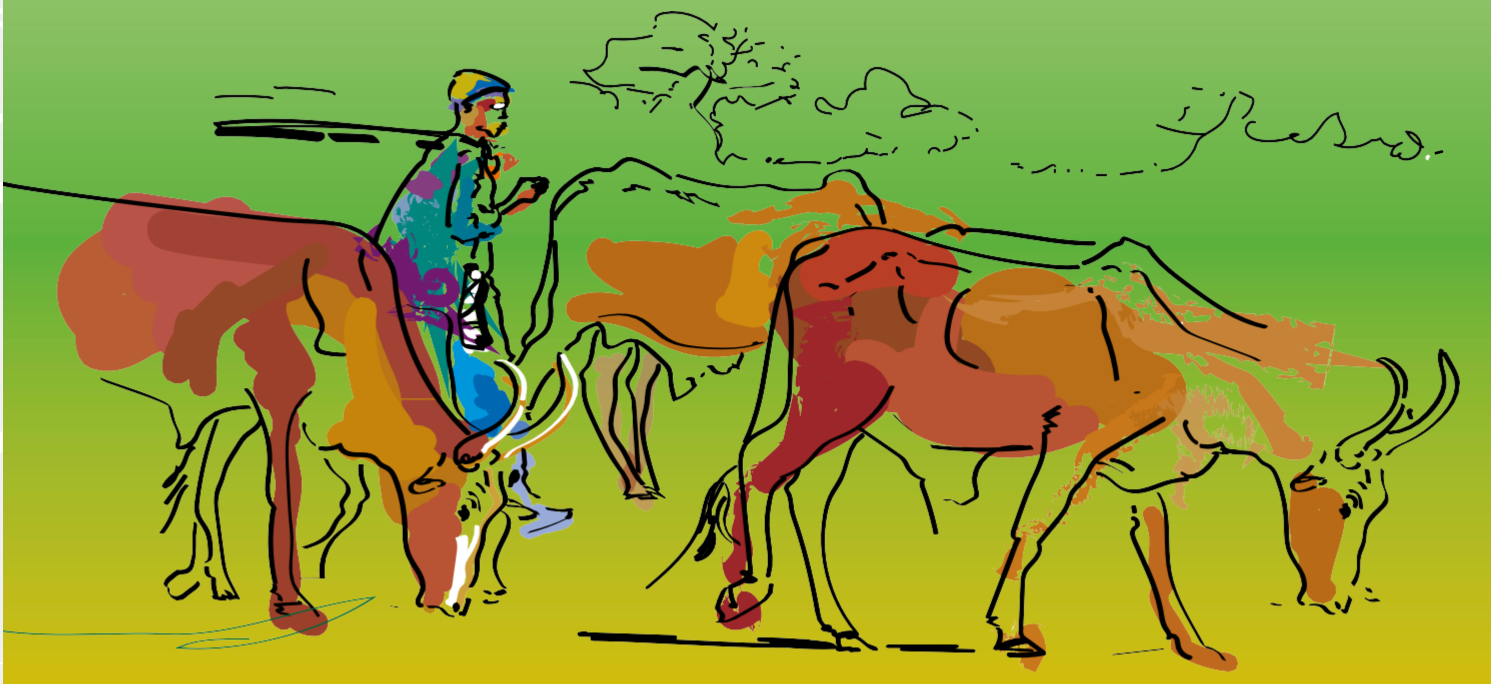
One Health

Surveillance of emerging animal diseases

Press kit • April 2021



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CIRAD is the French agricultural research and international cooperation organization working for the sustainable development of tropical and Mediterranean regions.

Along with its partners, it is convinced that agriculture has a central role in the major transitions required to guarantee a sustainable future for every country in the global South. Generating and sharing new knowledge, contributing to innovation processes and building the capacity and skills of stakeholders in those countries to support their sustainable development are the drivers of its operations. In particular, its activities centre on issues such as biodiversity, the agroecological transition, climate change, health (of plants, animals and ecosystems), the development of rural territories, and food systems.

CIRAD works in some fifty countries on every continent, thanks to the expertise of its 1650 staff members, including 800 researchers, backed by a global network of partners.

Introduction

What is an emerging or re-emerging disease?

An emerging infectious disease is an infection that has recently appeared within a population, whose incidence or geographical range is rapidly increasing. A re-emerging disease is one that, having already emerged, is now reappearing.

© J. C. Maillard,

75%
of emerging infectious diseases in humans come from animals

The pandemic caused by SARS-CoV-2 has taken us by surprise. The resulting health crisis has demonstrated the vulnerability of our societies to the emergence of a new, infectious and highly contagious pathogen. Yet the scientific community has been sounding the alarm for years: the number of events related to new infectious disease outbreaks has been growing steadily since the 1940s. Indeed, these events more than tripled until the 2000s.

These new diseases are mostly caused by viruses and bacteria, many of which circulate in animal species.

Wild animals and livestock are a major source of pathogens. Some are infectious in humans and cause health problems. Others are infectious in our domestic animals and can decimate livestock. What are these new infectious animal diseases, some of which are transmissible to humans (zoonoses) and cause epidemics or even pandemics? How does CIRAD's work contribute to the fight against the emergence of these diseases?

What are the risks of transmission and how can they be minimised?

What are the stages in the emergence of a disease, its spread and a pandemic?

When the virus is passed to humans, what measures must be taken to prevent it from spreading to the rest of the population?

How do these viruses pass from animals to humans?

These are some of the questions CIRAD's scientists are working on.

They study:

> **Pathogens** (viruses, bacteria, etc.), their diversity and their capacity to evolve, as well as their circulation in insect **vectors** (mosquitoes, ticks, etc.) and **hosts** (livestock or wild animals),

> Interactions between **humans** and **wild or domestic animals**, which result in the emergence and spread of new diseases,

> Ways to **monitor** diseases, to limit their emergence and to control them.

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CIRAD's research is guided by integrated approaches to health, known as "One Health"

CIRAD's research is guided by **integrated approaches to health, known as "One Health" or "EcoHealth"**, which explore the interdependence of ecosystem, plant, animal and human health.

What are the different "One Health" approaches?

One Health > An approach that takes account of the relations between human health, animal health and ecosystems. It establishes a connection between ecology and human and veterinary medicine.

EcoHealth > A health ecology concept that considers the effects of environmental contamination on human health.

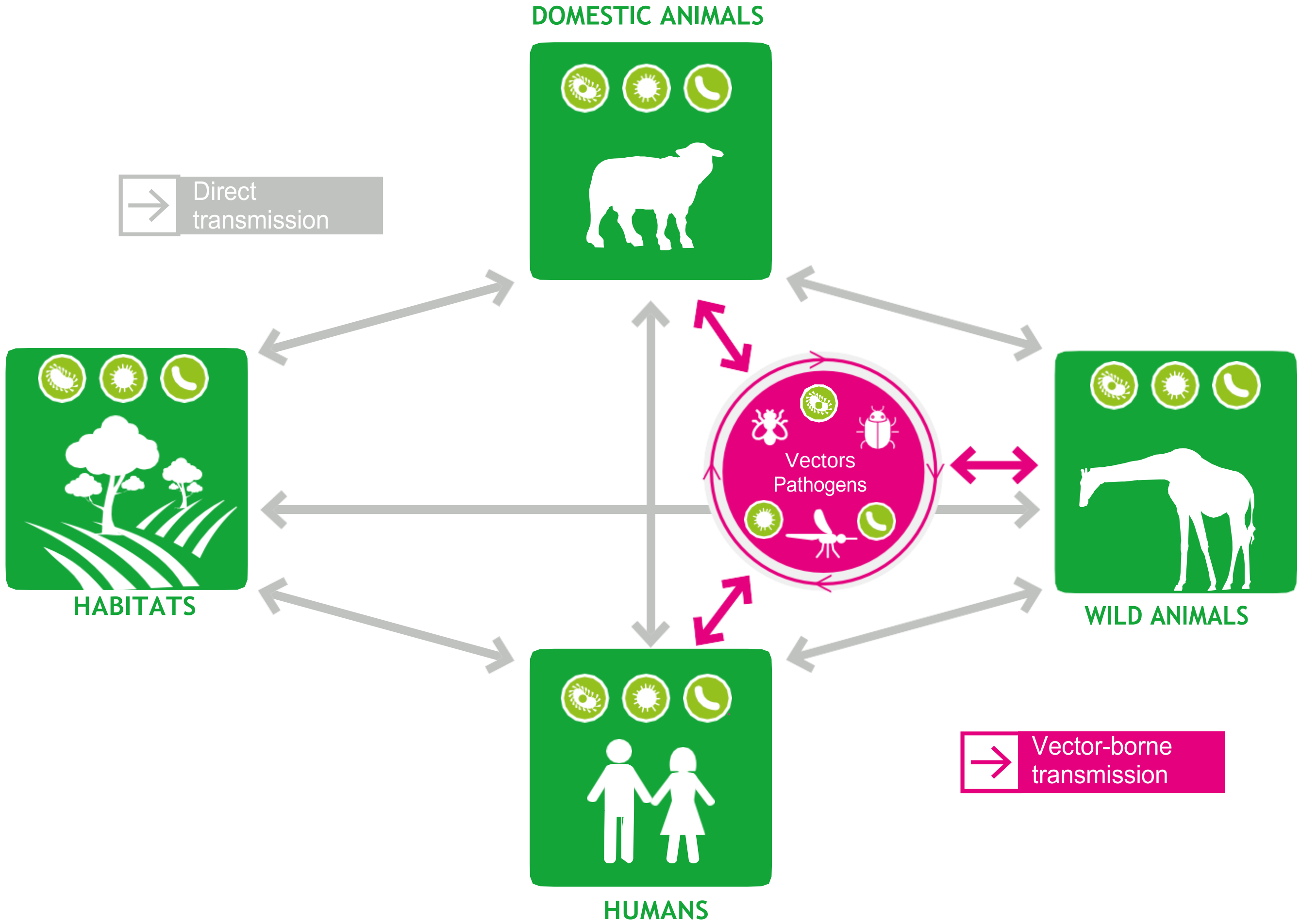
Planetary Health > Another ecosystem health approach, similar to the concept of EcoHealth, that studies the health of human societies along with state of the natural systems upon which they depend.

Within collaborative networks of veterinarians, scientists from all disciplines, health professionals and local communities, CIRAD's researchers apply their expertise, in particular on:

- The **animal diseases responsible for epizootics** that are spreading globally in livestock, such as African swine fever or peste des petits ruminants, or that regularly re-emerge through new strains, such as avian and swine influenza.
- **Emerging zoonoses**, which circulate **within livestock, wild animals** (such as MERS-CoV, Nipah virus, etc.) or **insect vectors** (such as West Nile fever, Usutu virus, Rift Valley fever, Japanese encephalitis, etc.).
- The issue of **antibiotic resistance** (the resistance of bacteria to antibiotics), which causes more than 700 000 deaths worldwide each year, as well as alternatives to antibiotics in livestock farming and aquaculture.
- The issue of disease **outbreaks**, and **global reflection on how to avoid pandemics**, advancing integrated approaches to health, which include plants and ecosystem health, from the local to the international level.

© L. Balberini, CIRAD

How is an infectious disease transmitted?



A host
is a living organism within which a pathogen spends all or some of its life-cycle.

A pathogen
is a microorganism, such as a virus, a bacterium, etc., that can cause disease in a living being (here, an animal or human).

A vector
is, in the animal world, generally a hematophagous arthropod (mosquito, tick, sandfly, tsetse fly, etc.). The vector is infected when feeding on a host carrying a pathogen, then transmits the infectious agent to a new host when it next feeds.

A reservoir
is an organism or an environment in which a pathogen can remain over time.

An interface
is a zone of possible contact between a pathogen and its host.

from Les dossiers d'Agropolis International, number 25, December 2019.

What is a zoonosis?

Today, a zoonosis (or zoonotic disease) is defined as an infectious or parasitic disease whose microbial or parasitic agents are naturally transmissible from animals to humans. These agents can be microorganisms (bacteria, viruses, microscopic fungi, protists-protozoa, prions) or larger parasites (such as helminths or parasitic arthropods). These agents will only be pathogenic in certain conditions, certain species and certain individuals. It is the interaction between the agent and the host, in other words the infected individual, that results in pathogenicity. (Taken from ***Les zoonoses, ces maladies qui nous lient aux animaux***, Quae, 2021).

Interview

Thierry Lefrançois, Director of the Biological Systems department at CIRAD

© Franck Dunouau

"Health governance based on the One Health concept is more necessary than ever to manage outbreaks"

Rapidly detecting emerging diseases in humans, but also in animals, in order to act quickly at the local level and to alert on a wider scale. These are two of the recommendations you make along with nine other experts, in an op-ed in Le Monde, to ensure that disease outbreaks do not become pandemics. Do you have evidence that this can work?

Thierry Lefrançois: Several multi-country regional networks set up by CIRAD, associating veterinarians, researchers and other health professionals, have proven effective in limiting the entry of animal diseases in specific territories, or in controlling them, in particular because they apply the "One Health" concept.

This is the case, for example, of two networks coordinated from two French overseas departments. The CaribVET network, led by CIRAD from Guadeloupe, includes the veterinary services from 33 countries and territories, along with international and regional organisations, research organisations and universities in the area. The One Health - Indian Ocean network, led by CIRAD from Réunion and associated with the SEGA One Health network, includes the veterinary services, human health services and research organisations from the five Indian Ocean Commission countries.

The different actions coordinated by CaribVET on avian influenza helped to prevent the disease from entering the Caribbean in 2016, through an early warning system and strengthened border surveillance.

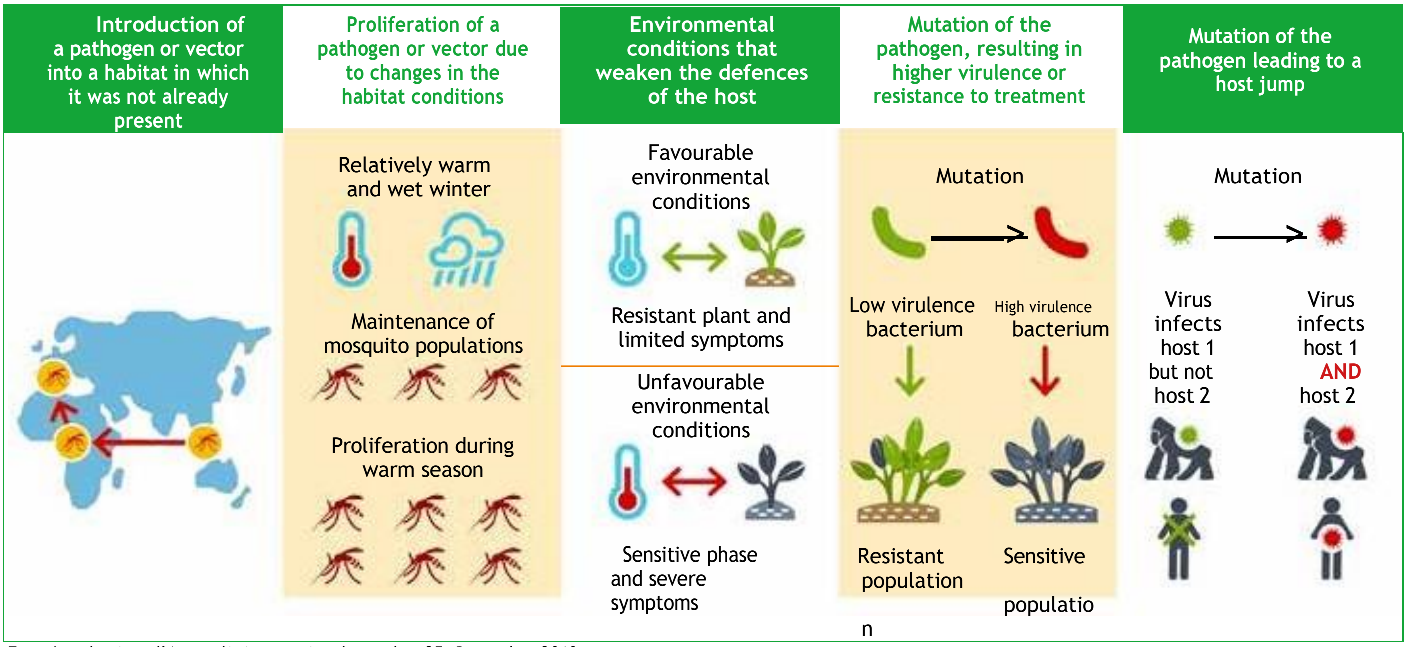
The One Health - Indian Ocean network contributed to controlling outbreaks of foot and mouth disease in Rodrigues Island (Mauritius) and Rift Valley fever, a disease transmissible to humans, in Mayotte in 2019. The latter crisis was managed in close partnership with health professionals. This network is currently carrying out extensive work on antibiotic resistance, another major public health issue.

With more than 15 years of experience, these two networks have. made tremendous efforts to strengthen coordination and to build trust between actors involved in animal and human health, in order to ensure effective information sharing.

These networks are guided by the "One Health" concept. What does this concept mean to CIRAD? What do you mean by integrated approaches to health?

T. L. Through the "One Health" concept, we consider that human, animal and ecosystem health are all connected. This approach may seem to be common sense, yet the gap currently existing

The factors likely to generate epidemic outbreaks



From Les dossiers d'Agropolis international, number 25, December 2019.

between doctors and veterinarian shows that its implementation is far from simple. CIRAD's strength lies in its capacity to build bridges between sectors that typically work in silos, and to make the "One Health" concept a truly operational strategy in the field.

To qualify this "integrated" health, we therefore take a multisectoral, multidisciplinary and multi-stakeholder approach: farmers, breeders, manufacturers, veterinarians, doctors, ecologists, etc. Our aim is to work hand in hand with actors in the field, and to establish a dialogue between them and their neighbours, as diseases do not respect borders.

The global "One Health" approach has completely transformed our vision of health. It encourages collaborations between professionals in these different fields and scientific disciplines, and fosters the dissemination of knowledge between different levels: from the local level, involving communities, to the national level, involving veterinary services, farmers and breeders, national parks, public health agencies, etc., or private actors.

Are there any similar networks in metropolitan France and at the European level that apply the "One Health" concept?

T. L. In France, three epidemiological surveillance platforms coexist: one on animal health, ESA, one on plant health, ESV, and a more recent one on food chain surveillance, SCA. These networks have brought together public and private actors to support epidemiological surveillance in France.

The French Epidemiological Surveillance Platform for Animal Health (ESA), set up in 2011 at the initiative of the French Ministry of Agriculture, now has 10 member organisations. The platform monitors around 20 health risks in livestock and wild animals.

Within the ESA platform, CIRAD draws on its experience in epidemiological surveillance in the global South and its role in international networks to head the Global Health Surveillance Unit (VSI), along with ANSES and the French Directorate for Food.

This global health surveillance continuously monitors diseases such as highly pathogenic avian influenza, African swine fever and bluetongue disease. Interactive maps show the location of outbreaks in the different countries and their evolution over time. This surveillance system demonstrated its effectiveness by rapidly detecting the sudden arrival of Schmallenberg virus in France in 2012, as well as outbreaks of bluetongue disease in 2006 and 2015. The ESA system therefore not only detects the arrival of epidemics at borders, but helps to coordinate surveillance and protection mechanisms within France.

At the European level, innovative networks and tools to predict and detect outbreaks that meet the requirements of health managers are being developed, through European projects such as MOOD (https://mood-h2020.eu/), which CIRAD has been coordinating since early 2020.

But this is just the beginning.

In your opinion, more must be done, and this is why you welcome the decision to create a "One Health" high-level expert council. Do you think this is essential to ensure the approach is applied at the international level?

T. L. The successive IPCC reports on climate change have resulted in some major international agreements, such as the 2015 Paris agreement. There is a vital need for an equivalent structure for health.

The goal of this completely independent high-level expert council will be to support the international organisations concerned, as well as the states, in producing recommendations for health policies, in order to better anticipate, monitor and react to outbreaks.

To be truly effective and operational, this council must bring together all of the actors involved in understanding and managing disease outbreaks: scientists from all disciplines and sectors and representatives of international organisations (WHO, OIE, FAO, UNEP, IPBES, etc.), in an interdisciplinary and intersectoral approach. In short, implementing the "One Health" concept at the international level, and rapidly ensuring the operational application of activities within the regional networks existing worldwide.

The recommendations of this council will need to be supplemented by research and development actions in all of the geographical areas that are confronted with outbreaks, especially in the most vulnerable countries, in particular in the global South.

PREZODE, a new international research and development initiative to prevent the risks of zoonotic disease outbreaks and pandemics

France, with the support of Germany, has launched an international research and development initiative aimed at preventing the risks of zoonotic disease outbreaks and pandemics, in particular by reducing pressure on biodiversity.

PREZODE, PREventing ZOonotic Disease Emergence, was presented during the One Planet Summit on Biodiversity on 11 January 2021. This major project will strengthen cooperation with the parts of the world the most exposed to the risks of zoonotic disease outbreaks: Africa, Asia, the Caribbean and Latin America.

Deforestation and biodiversity loss are sources of contacts between humans and animals, and of new disease outbreaks © C. Bourgoin, CIRAD

The animal epidemics that decimate livestock throughout the world

Every year, diseases kill animals, affecting livestock farms in different countries of the world and threatening the livelihoods of farmers.

As of 2020, 117 animal diseases were notifiable to the World Organisation for Animal Health (OIE), including 53 established by the OIE as high-priority diseases.

A closer look at three of these diseases CIRAD studies that often make the headlines: African swine fever (ASF), peste des petits ruminants (PPR) and avian influenza.

What is an epizootic?

An epizootic is a disease that affects a large number of animals from one species, or from a group of species, over a limited period. An epizootic can vary in magnitude. If it spreads to one or several continents, it then becomes a panzootic, the equivalent of a pandemic in humans.

African swine fever: a global invasion

African swine Fever (ASF) is a highly fatal and contagious haemorrhagic disease of domestic and wild pigs, with a transmission rate and a case fatality rate of up to 100 %. The virus can survive for several weeks in meat, processed products, food waste and agricultural effluents.

Pathogen

Virus of the genus *Asfivirus*, family *Asfarviridae*, it remains infectious in carcasses for several months

Hosts

Pigs
(domestic and wild)

Reservoirs and vectors

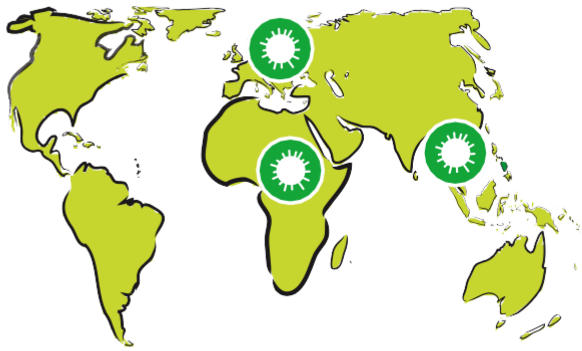
Wild African suids
(warthogs and bush pigs)
Soft ticks of the genus *Ornithodoros*

Transmission

Direct
By direct contact with an infected animal or by absorption of contaminated waste

Indirect
Through a vector (ticks of the genus *Ornithodoros*) and/or by contact with soiled materials (litter, feed, clothing, equipment, etc.)

Distribution



In July 2020, the World Organisation for Animal Health (OIE) and the Food and Agriculture Organization of the United Nations (FAO) launched an international initiative for the control of ASF, which is present in Africa, and now also in Asia and Europe. CIRAD contributes to this initiative through different research projects aimed at advancing knowledge, especially on the modes of transmission and spread of the disease.

African swine fever (ASF) is a serious threat to pig farms. No vaccine is available yet. © P.-Y. Le Gal, CIRAD

Since its discovery in East Africa in the early 20th century, ASF has spread through domestic pigs across the whole of sub-Saharan Africa.

The disease first spread beyond the African continent in the late 1950s, reaching Europe (through Portuguese imports of contaminated pork in 1957), Brazil and several countries in the West Indies. ASF was finally eradicated in these regions in the mid-1990s, except in Sardinia.

The second time the disease spread beyond Africa was in 2007, to Georgia, then Russia and Eastern Europe (Bulgaria, Hungary, Poland, Romania), and Western Europe. After Poland, Belgium was affected in 2018, then Germany in 2020, as well as China, probably via Russia. The disease then spread to the neighbouring Asian countries, despite China culling infected pigs in an effort to contain the epidemic.

A risk of destabilisation of the world meat market

Pork accounts for almost 40 % of meat consumption in the world. In late 2019, further to the spread of the disease in Asia, which has two thirds of the world's pig population (half of which is in China), around one in four pigs died of the virus. By September 2019, China alone had suffered economic losses estimated at 141 billion US dollars.

Chinese livestock losses disrupted the global market for pork. China, as a major producer and consumer country, drove up prices at the international level, forcing some consumers to fall back on other meat products. Faced with this sudden shift in demand, the disorganisation of international livestock production chains is to be feared, with an intensification of livestock farming that could cause other diseases.

Moreover, the drastic reduction in Chinese pig stocks has meant imports of animal feed have plummeted, which has had serious consequences for cereal sectors throughout the world. The fall in world soybean prices, for example, has heavily impacted American producers, the main exporters to China.

V. Porphyre © CIRAD.

Asia was seriously affected by ASF in 2019.

Focus: Wild animals and soft ticks: what roles in the transmission and spread of ASF?

At CIRAD, scientists are working on the interface between wild reservoirs of the disease and domestic pig farms. These studies help to better understand and monitor the mechanisms involved in the spread of ASF between farms, in the environment and at the interface of the two, and therefore to assess the risks for farms.

What role do wild suids play in spreading and maintaining ASF in the environment?

This is the question several researchers are trying to answer in Southern Africa and Madagascar. In contact with the soft tick *Ornithodoros moubata*, warthogs in Southern and East Africa are a permanent and very diverse source of viruses (more than 25 different strains), and are therefore a potential threat to the pig farming sector in Africa and the rest of the world. The researchers are also studying the dynamics of livestock movements in the domestic sector, as well as the potential interfaces between the wild cycle and the domestic cycle of the disease.

In Europe, for several years teams from CIRAD have been coordinating a European network to understand the role played by the wild boar (*Sus scrofa*) in maintaining the virus in the environment. Indeed, since the introduction of ASF in Europe in 2007, the high densities of wild boars, correlated with the capacity of the virus to survive in frozen carcasses over winter, have contributed to maintaining a permanent source of epidemic in the forests of Eastern Europe. This is a serious threat to the European Union's pig farming sector.

Nif-Naf (2019-2022. Madagascar, South Africa, Mozambique)

This research project, coordinated by the University of California, in collaboration with CIRAD, studies the emergence and transmission pathways of transboundary animal diseases such as African swine fever (ASF), as well as the interfaces between wild and domestic animals. Eric Etter, a veterinary epidemiologist at CIRAD, is the co-principal investigator of the studies conducted in the context of Nif-Naf.

The goal of this project is to improve knowledge of ASF and other transboundary diseases in Southern Africa, thanks to ambitious interdisciplinary research. Intensive field data collection was carried out: wild and domestic pig and tick sampling, and camera traps. Experimental studies were conducted in seven study areas in Madagascar, South Africa and Mozambique: tick competence to transmit viruses, variability due to extrinsic and intrinsic factors, such as temperature, humidity or tick microbiome, etc.

https://www.asf-nifnaf.org/

Ticks do not transmit the disease in Europe, but they play a major role in Africa.

As a reservoir and vector of the virus, the soft tick *Ornithodoros* and its vector competence have been studied. It has thus been shown that the success of transmission varies according to the species of tick tested, as well as the viral strain. The researchers at CIRAD have answered a key question in Europe: the European ticks *O. erraticus* and *O. verrucosus* are unable to transmit through their bite the viral strains currently circulating in Europe. However, they remain infectious long enough to cause the disease in pigs that ingest them. But the bioecology of these ticks mans that the probability of such a transmission event, which has not yet been estimated, is assumed to be low. Conversely, CIRAD's research has confirmed the major role of the African tick *O. moubata* in transmission by bite, as well as its capacity to transmit the virus to its descendants. However, the success of transmission depends on the rates of viral replication and dissemination in ticks, as well as on the effect of the infection on the tick. Indeed, the immune response to ASF developed in ticks may be more or less effective. But this process is one of the factors that influences the aptitude of ticks to multiply and transmit the virus.

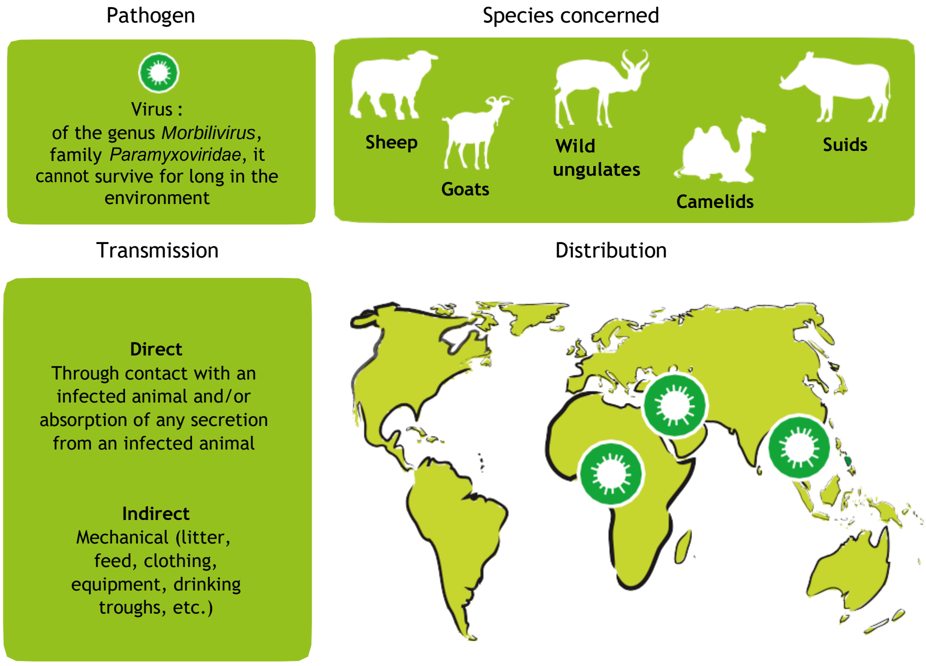
Expertise
François Roger, Laurence Vial, Eric Etter, Ferran Jori

Peste des petits ruminants: aiming for eradication by 2030

Peste des petits ruminants (PPR) affects almost a billion sheep and goats in Africa, the Middle East and Asia, but more than 80 % of these domestic ruminants ensure food security and economic autonomy for the people there, particularly women. A Global strategy for the control and eradication of PPR by 2030, coordinated by FAO and OIE, is underway. CIRAD, as an International Reference Laboratory on the disease for OIE, FAO and the European Union, contributes to the strategy by coordinating or participating in a number of projects.

Small ruminants ensure food security and economic autonomy for many people in Africa, the Middle East and Asia © B. Faye, CIRAD

Peste des petits ruminants (PPR) is a highly contagious viral disease of sheep and goats.



Described for the first time in 1942 in Côte d'Ivoire, peste des petits ruminants (PPR) causes substantial losses in flocks. Currently present in Africa, Asia and the Middle East, this highly contagious disease continues to emerge in new countries. In particular, it was detected in 2016 in Georgia, and in 2018 in Bulgaria close to the Turkish border.

CIRAD is one of the three OIE Reference Laboratories for PPR, and is also the EU Reference Laboratory. Under this mandate, CIRAD was involved in confirming the diagnosis of the disease during the outbreak in Bulgaria in 2018, which has since been brought under control. It provided expert epidemiologists in order to support investigations and to implement control measures.

Assessing the level of viral transmission

CIRAD is studying the dynamics of transmission and the persistence of the disease, from the smallest scale (genetic evolution, host-pathogen interactions), to the largest (spread of PPR through transboundary movements of animals or within complex socio-ecosystems at the interface between wild animals and livestock). Thanks to the information obtained through this research, the scientists assess the level of viral transmission in the endemic area. They thus determine the immunisation coverage required to halt this transmission and to eliminate the disease. These actions contribute to the programme to eradicate the disease by 2030.

Reducing the costs of eradication by targeting surveillance and vaccination efforts

Vaccination is one of the key tools of the eradication programme. The vaccine developed in 1989 by CIRAD and the Pirbright Institute has proven effective in the last few decades, but it does not enable serological differentiation between vaccinated animals and naturally infected animals. To reduce the cost of PPR control, CIRAD has undertaken to **develop a new vaccine** capable of differentiating between infected animals and vaccinated animals, as well as a therapeutic vaccine.

High-risk territories and animal populations are identified in order to be specifically

Vaccination is one of the key tools of the PPR eradication programme.
© CIRAD

targeted in surveillance and vaccination control strategies, which increases effectiveness while reducing costs. This work is initiated or supported by CIRAD, through different projects such as LIDISKI (CIRAD), PRAPS (OIE), EcoPPR (ILRI), and EUFMD (FAO). Research is based on semi-quantitative analysis and risk mapping, with the active contribution of local actors, through participatory methods and a sub-regional approach. These approaches are essential to reduce the cost of eradicating the disease while increasing the chances of success.

LIDISKI (2020-2023. Nigeria)

This project associates research and development in Nigeria, by contributing to building local capacities to control animal diseases. In particular, it focuses on control of peste des petits ruminants (PPR) and Newcastle disease, which are two of the main animal diseases affecting livestock in the country. LIDISKI is coordinated by CIRAD, and has received 2.5 million euros of funding from the European Union through the DeSira initiative.

The project is aimed at local actors, through training, disease notification and the collective construction of surveillance and control strategies. To achieve this, CIRAD works closely with community animal health workers, veterinary services, farmers and private livestock companies.

http://www.lidiski.org/

Building diagnosis, epidemiology and risk mapping capacities in the different countries

As an OIE Reference Laboratory and Collaborating Centre for epidemiology and training, CIRAD is involved in numerous initiatives to support the efforts made at the global level to control and eradicate PPR, especially training people working in animal health in PPR diagnosis methods, the epidemiology of the disease and risk mapping, etc. Educational materials, training modules and webinars are also provided to partners and country veterinary services. These help to build the capacities of the actors in charge of these activities in the field (field workers, veterinarians, etc.) and foster greater operational effectiveness and the transfer of methods and tools (diagnosis, surveillance, vaccination, etc.). Finally, with the support of OIE and FAO, CIRAD is working to design a training programme in line with the skills to be developed in the different countries, with the goal of effectively implementing the PPR eradication programme.

Expertise
Geneviève Libeau, Arnaud Bataille, Cécile Squarzoni-Diaw

CIRAD is actively involved in training people working in animal health in PPR diagnosis methods, the epidemiology of the disease and risk mapping.
© G. Libeau, CIRAD

Focus: Transmission and spread of PPR to wild animals: what are the risks?

For more than five years, CIRAD has been working in close collaboration with its partners in the global South and from other international institutions (Royal Veterinary College, Wildlife Conservation Society) to study the role of wild animals in the epidemiology of PPR. This research is aimed at implementing appropriate measures to manage wild-domestic animal interfaces. A closer look at an initiative conducted in Mongolia further to the detection of the disease in 2016.

In Mongolia, a serious PPR epidemic in 2016-2017 caused significant losses of livestock, but also of saiga antelopes, a rare species endemic to the region. In 2019, at the request of local actors, CIRAD mapped contacts between saiga antelope populations and livestock herds. This process helped to identify the times of the year and places where domestic and wild populations were able to interact, and therefore to transmit the virus to one another. This research led to recommendations in terms of PPR detection and control in this region, concerning management of the water points that were points of contact between wild animals and livestock.

Expertise
Véronique Chevalier, Annelise Tra

Domestic ruminants transmit PPR to saiga antelopes, a protected species in Mongolia. © CIRAD

Influenza, viral strains that are constantly mutating

FAO, OIE and WHO have been working together since 2005 against animal and zoonotic influenza, within the OFFLU network, which supports disease control activities by the veterinary services. CIRAD contributes to these efforts through research in Asia focusing on avian influenza, which was launched in 1997 further to the emergence of the H5N1 virus, and more recently the H5N8 virus, reported in Europe since 2019.

In the last 10 years, new strains of highly pathogenic avian influenza have emerged and rapidly spread throughout the world © M. Boni

Flu, otherwise known as influenza, is a highly contagious viral disease that affects birds as well as mammals. These influenza strains are highly diverse, especially due to regular mutations and recombinations during interspecies transmission.

Pathogen

Virus: of the genus *Influenzavirus A*, family *Orthomyxoviridae,* it is very resistant in the environment.

Influenza A viruses have high “plasticity” and evolve constantly by exchanging their genes or acquiring mutations, some of which may enable them to infect humans.

Reservoirs

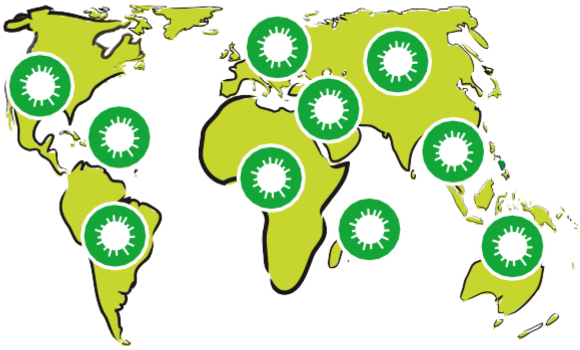
Wild birds

Transmission

Direct
By absorption of any contaminated animal secretion and/or product (mainly fecal and respiratory)

Indirect
Mechanical (litter, feed, clothing, equipment, etc.)

Distribution



Avian influenza, first discovered in the late 19th century in Italy, was accurately differentiated from other diseases with similar symptoms in the 1950s. Avian influenza epidemics have been subject to compulsory notification to OIE since 1964, and affect every continent.

Although not all avian influenza viruses are transmissible to humans, they are carefully monitored because of their zoonotic capabilities. Indeed, all of the major pandemics of the 20th century originated in animal influenza viruses: Spanish flu in 1918 (between 50 and 100 million deaths), Asian flu in 1957 (70 000 deaths), and Hong Kong flu in 1968 (56 000 deaths).

Determining the role of human activities in the recurrence and spread of avian influenza in Southeast Asia

In 1997, a highly pathogenic H5N1-type virus emerged in Southeast Asia. It then spread to Europe in 2005 and to Africa in 2006. Its spread, its survival in the environment and its epidemiological cycle still raise many questions. To answer these, CIRAD launched a series of studies at the onset of the crisis to ensure better understanding of the disease and its virus, but also to anticipate its progression.

Through this research, CIRAD and its partners discovered that certain environments are particularly suited to the survival and spread of influenza viruses, especially the association of rice growing and poultry farming, habitats that foster contacts between wild and domestic birds.

Since then, researchers at CIRAD have focused on small-scale, semi-commercial and family poultry farming in Vietnam. Field studies have shown that farmers tend to respond to outbreaks of highly pathogenic avian influenza (HPAI) by rapidly selling their poultry in order to limit their financial losses. In some countries, intensive industrial farms also adopt this practice. Since poultry are mixed with other birds on markets and in trade networks, this practice increases the risk of disease transmission on a larger scale. To tackle this problem, the scientists work with farmers to identify alternatives and to limit health risks, such as selling diseased birds as feed for pythons and crocodiles farmed nearby.

Identifying the most effective vaccination strategies depending on the territory

Since 2008, several studies have been conducted on the assessment of monitoring and control strategies for avian influenza, in collaboration with international organisations such as FAO, along with studies since 2014 in the context of public private partnerships with Ceva Santé Animale. These have resulted in the development of the **EVACS tool (Evaluation of vaccination strategies against animal diseases)**, which is capable of identifying the most effective vaccination strategies depending on the socio-economic context and the level of organisation of poultry sectors in the different countries of the world, in both the North and the South. These projects also assess the risk of these pathogens spreading between farms with different levels of biosecurity, as well as the risk of them spreading from the local to the global level through international value chains. These partnerships contribute significantly to the transfer of tools developed by research and to the continuity and impact of actions conducted in the field.

In Vietnam, some farmers risk selling their diseased poultry on markets in order to avoid culling © A. Delabouglise, CIRAD

"One Health Poultry Hub", a veterinary public health network in Asia

Faced with the growing demand for eggs and poultry meat in Asia, around 30 partners, including CIRAD, formed a public veterinary health network in 2019, the "One Health Poultry Hub". Its goal is to tackle the emergence of zoonoses and to make poultry production safer. In Southeast Asia, bacterial food poisoning is common. Moreover, this region remains a hotbed of avian influenza. The overuse of antibiotics in poultry farming is also a reality there. Beyond the surveillance of viral or bacterial diseases, the goal of this network is to identify high-risk behaviours, processes and environments in order to correct them, and to design appropriate diseases control plans in order to make poultry production safer. Bangladesh, India, Sri Lanka and Vietnam are the four countries directly concerned by the actions of the network.

Expertise
Flavie Goutard, Marisa Peyre

Focus Wild migratory birds: what role in the introduction of the H5N8 virus in Europe?

Through the AI-TRACK project, scientists from CIRAD, the French National Veterinary School of Toulouse and the IDeVet laboratory are studying the mechanisms involved in the introduction of the H5N8 virus in poultry farms in the Gers department in France. Present in Europe since 2019, H5N8 has resulted in substantial culling measures and restrictions on livestock movement in France since late 2020.

CIRAD focuses in particular on the interface between wild birds and duck farms. Samples are taken from wild birds by an ornithologist accredited by the French National Museum of Natural History, in order to identify the virus.

The H5N8 virus has already been identified in more than 50 bird species in Europe. The goal of the research under AI-TRACK is to determine which of these species are the most likely to transmit the virus to farms. Wild migratory birds, and in particular ducks, are suspected of importing these avian influenza viruses into Europe, during the autumn migration from the north of central Asia via Eastern and Northern Europe. Some local species could then act as a relay between these species and duck farms. The possible role of certain human activities, such as hunting, in the wetlands visited by wild ducks is also being studied.

Expertise
Julien Cappelle

Wild migratory ducks are strongly suspected of importing the H5N8 virus into Europe. D. Cornelis © CIRAD

Emerging or re-emerging zoonoses, diseases that pass from animals to humans

With their expertise on animal diseases, the scientists at CIRAD are leading the way on outbreaks of zoonoses, diseases of wild or domestic animals that are transmitted to humans.

In the list of around [10 priority diseases] for research and diagnosis drawn up by the World Health Organization (WHO), all are zoonoses caused by viruses.

The goal of the research is to understand the emergence of these diseases in humans and to map the risks in order to protect animal and human populations

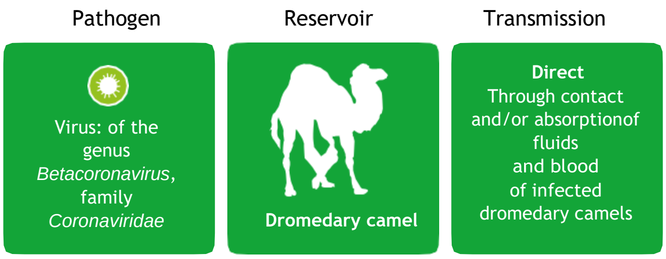
The animal reservoirs of viruses that can be transmitted to humans

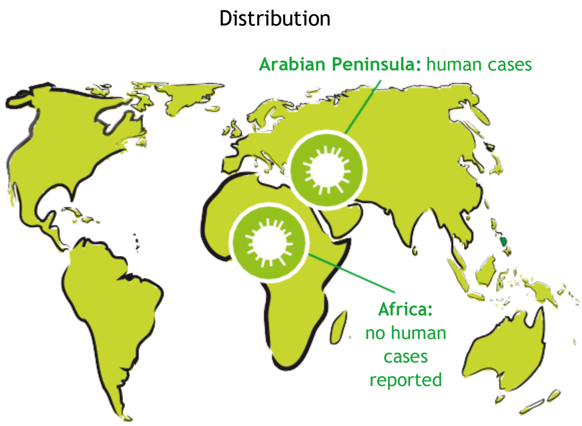
In some parts of the world, dromedary camels, bats, rodents and dogs are reservoirs of viruses responsible for zoonoses, in other words diseases that can be transmitted to humans. A closer look at the viruses they host, which researchers are tracking.

The dromedary camel, a reservoir of MERS-CoV, a coronavirus, in Africa and the Arabian Peninsula

MERS-CoV causes Middle East respiratory syndrome, a fatal disease in humans. Since it was first identified in humans in 2012 in Saudi Arabia, it has infected more than 2 500 people and caused 800 deaths. With a case fatality rate in humans of almost 40 %, and with no treatment or vaccine currently available, this viral disease is one of the priority emerging diseases on the list established by the WHO.

MERS-CoV (Middle East respiratory syndrome coronavirus) is a coronavirus that circulates actively in dromedary camels in the Arabian Peninsula and Africa © B. Faye, CIRAD.





MERS-CoV is a coronavirus that circulates actively in dromedary camels in the Arabian Peninsula and Africa. It is similar to the virus of the severe acute respiratory syndrome (SARS) caused by SARS-CoV, which infected more than 8 000 people in 2002, affecting 25 countries and causing 800 deaths. It is also similar to SARS-CoV-2, the virus that causes COVID-19.

Until now, only the Arabian Peninsula has had human cases. But MERS-CoV is present in dromedary camel populations in several African countries. To solve this puzzle, an international collaboration, headed by the Institut Pasteur in Hong Kong and involving CIRAD, has carried out surveys, sampling and genetic analyses of infected dromedary camels and humans. This research has revealed genetic differences between the MERS-CoV strains circulating in dromedary camels in Africa and those in the Arabian Peninsula, which could partly explain the mystery.

Research on the mechanisms and factors of transmission from camel and dromedary populations to humans is ongoing, especially in Ethiopia. The risks are real, since dromedary camels are of great importance in the countries in which they are found, and live in close proximity to humans.

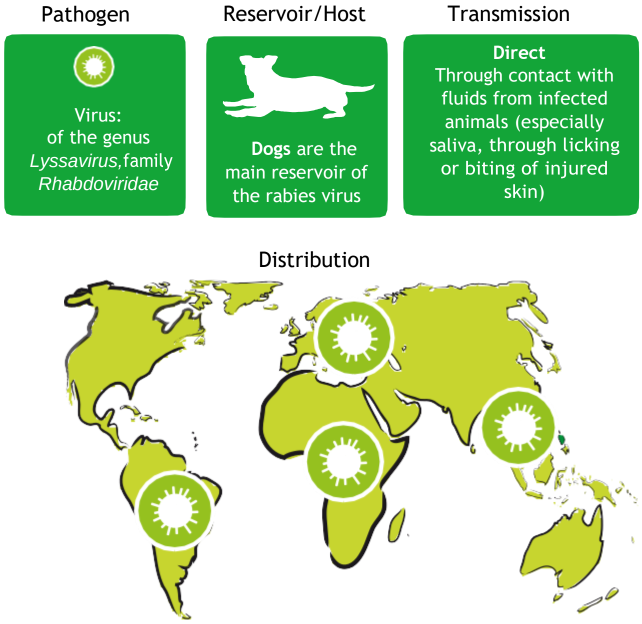
Expertise

François Roger

The importance of vaccinating dogs, carriers of rabies

If it is not treated before the appearance of symptoms, the rabies virus causes fatal encephalitis, in humans as well as in many other mammals. Although there is a vaccine, the disease is a major health issue in Africa, Asia and the Indian Ocean, including Madagascar. In the context of rabies control, OIE has just launched a major campaign for global eradication through the vaccination of dogs.

Rabies, a disease that may seem to be from another time, is nevertheless still present in many places, even in Europe. **In Cambodia**, one of the countries most affected by this virus, almost 800 people die of it every year. Vaccination and dog population management are still the most effective ways to contain the disease, but such actions can prove difficult to implement in some countries. OIE is currently resuming rabies eradication programmes and is launching a vast dog vaccination campaign, in particular using mapping of priority areas.



Mapping the risks in order to target vaccination campaigns

To support vaccination and control strategies, the teams at CIRAD are studying the risk factors that lead to the introduction and propagation of the disease. **In Tunisia and Senegal**, the veterinary services and health agencies have thus produced risk maps, which the health authorities can use to deploy vaccination and control actions based on the risk of dog populations. The effectiveness of these vaccination campaigns is also assessed, especially in terms of the immune response of animals to the vaccine.

Other scientific work focuses on the mechanisms of rabies virus transmission. The findings have shown, for example, that although rabid dog bites are the main cause of human cases, licking is also responsible for a significant number of cases.

Studying the relations between people and dogs

Dogs gravitate around people, especially through their feeding activities. Better understanding of the characteristics of dog populations and of their relations with humans are therefore key elements in reducing the number of bites. In Cambodia, the researchers are thus studying the dynamics of renewal in dogs and their relations with human populations. Finally, they are working to develop transmission models that will be used to propose dog vaccination strategies that are tailored to the context in Cambodia and, more broadly, in Southeast Asia.

Expertise

Véronique Chevalier

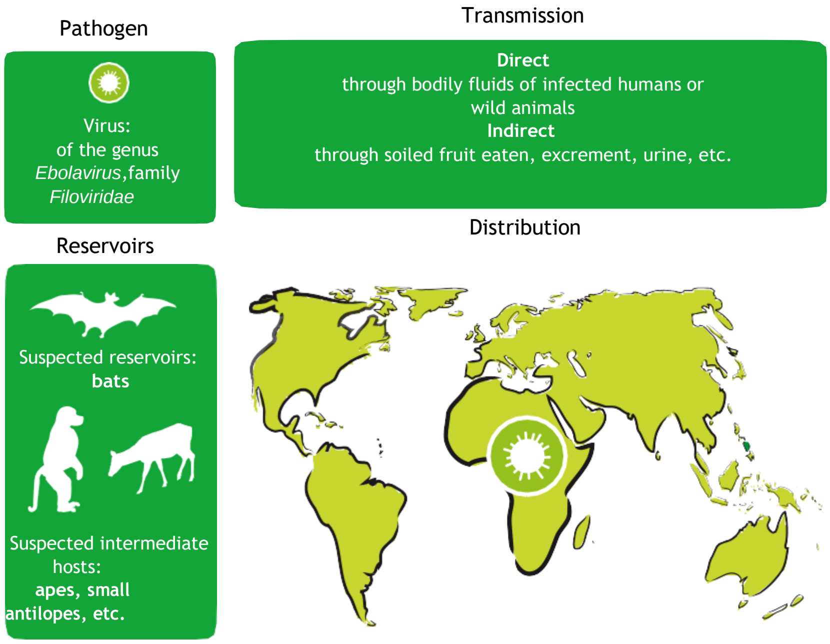
© J. Cappelle, CIRAD

Ebola, Nipah, Marburg, coronavirus, etc. Many viruses are spread by bats.

Tracking the viruses that circulate in different bat species: Ebola, coronavirus, Nipah

Ebola: viruses suspected of circulating in bats

Ebola virus disease is a severe haemorrhagic fever, with a case fatality rate in humans of around 50 %. The first human case was detected in 1976. Since then, WHO has recorded 29 Ebola outbreaks in the world. The Democratic Republic of the Congo is currently facing its 11th outbreak. There is a vaccine, and treatments exist. The animal reservoirs of the virus have not yet been formally identified, but several studies point to bats.



In partnership with IRD, the Institut Pasteur and OIE, CIRAD has been working since 2007 on Ebola virus disease through studies on bats, the suspected reservoirs of the virus. Two projects are currently underway in Africa: Ebo-SURSY, which is coordinated by OIE and located in 10 African countries (Senegal, Guinea, Côte d'Ivoire, Liberia, Sierra Leone, Cameroon, Gabon, Republic of the Congo, the Democratic Republic of the Congo, and the Central African Republic), and Ebo-Health, which is coordinated by IRD and focuses on Guinea.

Although no active Ebola virus has so far been identified in bats, several virological studies have reported virus fragments. In order to refine these results and to clearly identify the bat species that are carriers, scientists from CIRAD trap bats and take fluid samples from them.

Measuring the risk of emergence

To increase their chances of detecting traces of the Ebola virus in bats, the researchers are conducting extended genetic and serological studies. By comparing this data with ecological knowledge, such as habitat use, movement, reproduction and feeding, the scientists attempt to predict zones and periods with a high risk of emergence. The modelling teams at CIRAD then build emergence risk maps, at the local, regional and national scales.

Participatory epidemic surveillance

CIRAD is also working on epidemiological surveillance of ebolaviruses. This holistic approach includes wild animals, domestic animals and humans. To achieve this, the scientists work in close collaboration with local communities, veterinary services, national parks, local universities and Ebola research centres, which are key allies on the front line of Ebola virus disease outbreaks. The different actors are trained in participatory surveillance approaches. These consist in establishing a permanent dialogue and involving local communities in identifying the events that could signal the emergence of haemorrhagic fever diseases.

The local people also participate in surveys and share their information on the location of bats, their favourite trees, and the caves in which they live. When a significant site for the study of the animals has symbolic importance for the locals, offerings are made and permission is sought from the authorities in the nearby villages.

Expertise
Mathieu Bourgarel, Hélène De Nys

Ebo-SURSY (2017-2024; Central and West Africa)

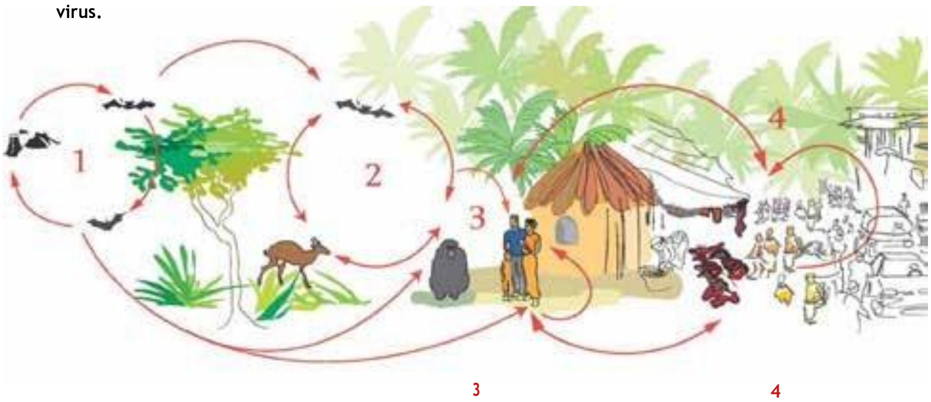
The recent outbreaks of zoonotic diseases in Africa led to the launch of this project, which aims to improve detection systems in 10 Central and West African countries for five zoonoses: Ebola, Marburg, Rift Valley, Crimean-Congo and Lassa viral haemorrhagic fevers, as well as coronaviruses. Ebo-SURSY is financed by the European Union and coordinated by OIE. CIRAD received a budget of 1.8 million euros to develop different activities, including: the identification of animal species that are virus hosts and reservoirs; the study of interspecies contact mechanisms; and the implementation of participatory disease surveillance and early detection systems.

In Zimbabwe, the hunt for coronaviruses has begun

Coronaviruses are a family of viruses whose “alpha” and “beta” types affect mammals. SARS-CoV-2, which is the cause of the COVID-19 pandemic, is a betacoronavirus. Several months ago, Zimbabwean and French researchers identified different types of coronaviruses in two bats colonies in the Kwekwe and Hurungwe districts in central and northern Zimbabwe.

At these sites, the team of researchers from CIRAD are collecting biological samples from mammals, especially bats and rodents, and conducting virological and serological analyses. Ecological studies of the wild species that act as reservoirs for certain viruses are also underway.

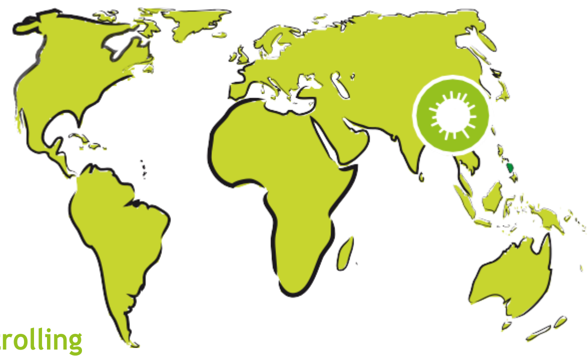
Circulation and transmission of Ebola viruses in a forest socio-ecosystem: contacts and possible transmission from the suspected reservoir, bats, to towns



Nipah, a virus carried by bats *(Pteropodidae)* in Southeast Asia

Pathogen	Reservoir	Transmission
Virus: Nipah, family Hénipavirus Symptoms: encephalitic form and respiratory form	**Bats of the genus *Pteropus***	**Direct** from other animals or humans **Indirect** via the fruits or sap of contaminated palms

Distribution



Nipah virus infection is a serious emerging zoonosis in animals and humans. Since it first appeared in 1998 in Malaysia and Bangladesh, the virus has caused the death of more than 500 people.

Although the circulation of NiV has been documented in bats of the genus *Pteropus* in several countries, including Cambodia and Thailand, little is known about the risk of transmission of this virus to domestic animals and humans in Southeast Asia. Scientists from CIRAD and the Institut Pasteur have conducted research in Cambodia. Mobilising ecology, anthropology, virology and epidemiology, they have shown that the emergence of epidemics is strongly linked to human food and agricultural practices.

Monitoring and controlling the risks of transmission to humans in Cambodia

In collaboration with several research organisations, including the Institut Pasteur in Cambodia, CIRAD coordinates research aimed at better assessing the risk of NiV emergence in Cambodia, in other words its transmission to domestic animals or humans. Virological tests have been conducted on more than 3 000 bats in order to detect the presence of the virus, as well as on around 420 people who are in contact with these animals. The movements (tracked by GPS), the population dynamics and the diet of a Lyle’s flying fox (*Pteropus lylei*) colony, but also the circulation of NiV in the urine of these bats, have been studied. Associated with the observation of farming practices among local communities, this research contributes to better anticipating the risks of NiV emergence in the Cambodian context.

The first results reveal seasonal patterns both in population dynamics and in virus circulation. This has helped to identify certain periods in which local communities’ practices may put them at higher risk of infection. The telemetry study has also pinpointed areas with increased potential contacts between humans and bats.

Subsequently, interviews with local actors have revealed limited conflicts between bats and humans, but also a lack of perceived risk among local communities. Participatory approaches are being used to disseminate knowledge about the risk of emergence and the ecosystem services associated with flying foxes, in order to advocate the use of preventive measures that reconcile public health and conservation.

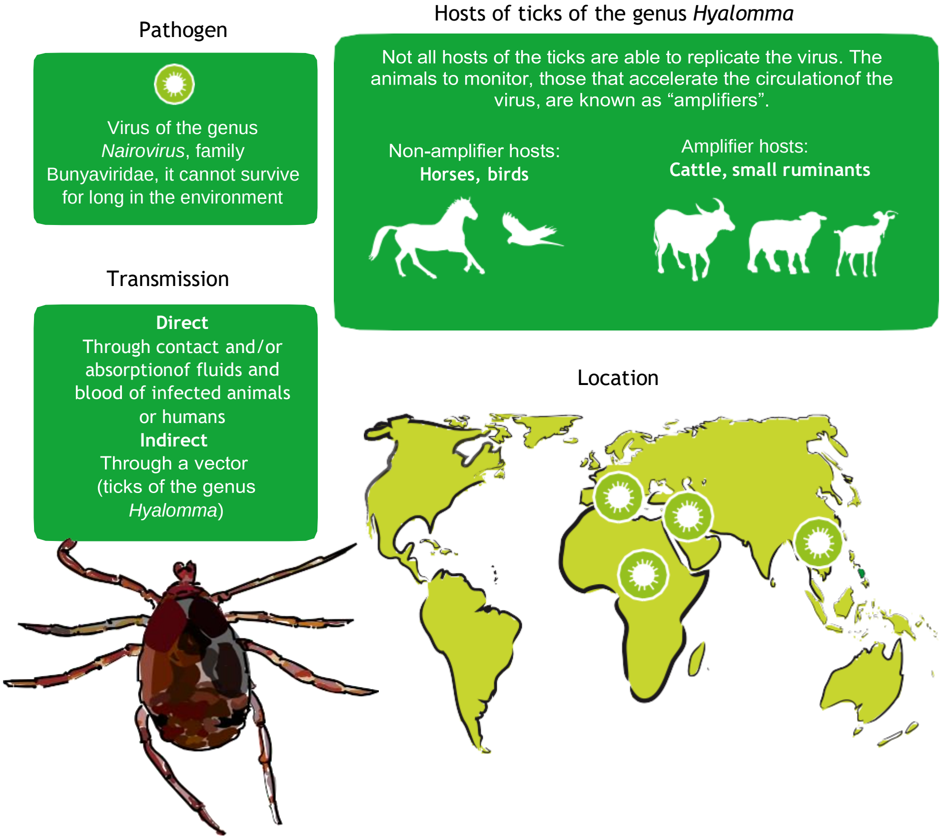
Expertise
Julien Cappelle

The insect vectors of diseases in humans and animals: vector-borne diseases

Pathogens can also be transmitted to animals or humans by vectors, which are certain types of hosts capable of transmitting the pathogens they carry to other types of hosts. Such diseases are known as "vector-borne". At CIRAD the main vectors studied are hematophagous arthropods, in other words mosquitoes, ticks and tsetse flies.

Crimean-Congo haemorrhagic fever, a disease transmitted by the tick *Hyalomma marginatum*

Crimean-Congo haemorrhagic fever can in some cases cause severe haemorrhagic fever in humans, with a case fatality rate of up to 40 %. The disease is contagious, but can also be transmitted by ticks of the genus *Hyalomma*. Although animals can catch the virus, they do not fall ill from it and have no symptoms, which makes it particularly difficult to detect the disease. There is currently no vaccine available.



For several years, researchers from CIRAD have been observing the progressive installation of the bont-legged tick, *Hyalomma marginatum*, in the south of France. A known vector of Crimean-Congo haemorrhagic fever virus, this species is expanding its range and is currently found in nine departments in southern France: Haute-Corse, Corsedu Sud, Pyrénées-Orientales, Aude, Hérault, Gard, Bouches-du-Rhône, Var, and Ardèche. Crimean Congo haemorrhagic fever virus has not yet been detected in France, although a strain of the virus was identified several years ago in Spain, causing the first human cases there in 2016, 2018 and 2020.

The bont-legged tick is spreading in France

This tick is accustomed to warm, dry climates, and it seems that climate change has encouraged it to spread into southern France. In order to isolate Crimean-Congo haemorrhagic fever virus, which this tick can carry, teams from CIRAD are collecting and analysing ticks on a large scale. Serological studies of domestic and wild ruminants are also being conducted in order to detect the presence of antibodies directed against the virus, a sign of viral circulation. In 2018, antibodies were thus found in cattle and small ruminants in Corsica, even though the virus was not formally identified.

The likelihood of a human catching Crimean-Congo haemorrhagic fever is nevertheless considered to be low, and undoubtedly indicates very high circulation of the virus in vertebrate animals and ticks. But the lack of symptoms in contaminated animals makes it very difficult to determine this level of circulation. This is therefore what CIRAD has been trying to do for several years: to understand the factors of propagation of the virus and monitor its emergence in the Mediterranean, before any human cases are reported.

Expertise
Laurence Vial

Involving citizens in reporting ticks

To improve surveillance of the tick *Hyalomma marginatum* in France, CIRAD encourages people to report it using the application created by the CiTique project. Users can also report other tick species. See citique.fr, the participatory research programme in which citizens can contribute to research on ticks and the diseases they transmit.

In southern France, six other tick species have also been reported in horse farms thanks to the collection of *Hyalomma marginatum*. All are potential vectors of diseases in animals, and some also in humans. In particular, the tick *Ixodes ricinus* transmits Lyme disease, and *Rhipicephalus sanguineus* is a vector of Mediterranean spotted fever in humans.

Rift Valley fever, a disease transmitted by mosquitoes of six genera and direct contact

Pathogen	Reservoir	Transmission
Virus of the genus *Phlebovirus*, family *Phenuiviridae*, it is highly resistant in the environment	No known reservoir It is thought to be maintained in populations of wild herbivores	**Direct** (main mode of transmissionin humans): through contact with infected tissue from diseased animals **Indirect** (main mode of transmission in animals): through the intermediary of at least six genera of mosquitoes, including *Aedes* and *Culex*

Distribution

According to a study published in 2020, vaccinating 20 % of cattle against Rift Valley fever could reduce the number of human cases by 30 %.
© D. Louppe, CIRAD.

Rift Valley fever is an acute viral disease in wild and domestic ruminants, transmitted by bites from mosquitoes of at least six genera, including *Aedes* (to which the Asian tiger mosquito belongs) and *Culex* (to which the common mosquitoes in France belong). This haemorrhagic fever is transmitted to humans mainly by direct contact with infected livestock. In some ecological contexts, vector transmission (by mosquito bite) may become the main transmission pathway to humans.

In 1990-1991 and 2008-2009, Madagascar suffered two major epidemic outbreaks, causing heavy losses of livestock and – for the second epidemic – an estimated 10 000 human cases, with 26 confirmed deaths. As well as posing a risk to public health, the disease is a major threat to livestock farms, where it is the cause of substantial economic losses: abortion storms and high mortality in young cattle, sheep and goats, and measures to prohibit sales of live animals.

A rapid detection test

To control the spread of the disease, in 2018 a team from CIRAD developed the first rapid and specific detection test for Rift Valley fever virus. The instant detection of the virus enables better prevention of outbreaks of this fever, such as the one that struck in Mayotte until summer 2019. This rapid detection test identifies all strains of Rift Valley fever virus.

During the epidemic-epizootic of 2018-2019 in Mayotte, this test was used to immediately differentiate between Rift Valley fever and other diseases. Thanks to this innovation, measures to treat and isolate infected animals can be implemented straight away, thereby limiting the spread of the virus.

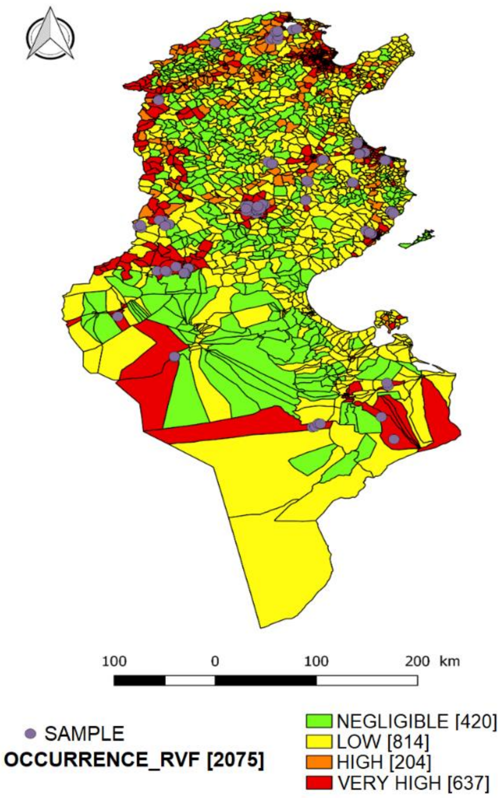
How does the virus spread and persist in ecosystems?

In West Africa (Senegal and Mauritania), Southern Africa and the Indian Ocean, CIRAD works in collaboration with its partners to understand the mechanisms of transmission and persistence of Rift Valley fever in different ecosystems.

By way of example, **in Senegal**, research has helped to determine the role of transhumant herds in the spread of the virus. In this country, the disease is transmitted by mosquitoes during the rainy season. But these insects are far less present during the dry season, yet the virus does not disappear and the disease outbreaks occur in different places from one rainy season to the next. The scientists have thus discovered that transhumant herds act as reservoirs for the virus and reinfect water points every time they stop at them.

Assessing the risk of introduction in territories not yet affected

Research is also conducted on risk factors for the introduction and spread of the disease, leading to the development of **risk maps** and helping to optimise surveillance in the field. CIRAD thus interacts with the veterinary services in West Africa (Senegal, Mali, Burkina Faso, Chad, Niger) and North Africa (Mauritania, Morocco, Algeria and Tunisia) to produce risk maps and to deploy risk-based surveillance and control programmes.



This type of risk map (here Tunisia) is used in particular to optimise vaccination strategies, by targeting priority areas © S. Kalthoum

Expertise
Véronique Chevalier, Catherine Cetre-Sossah, Cécile Squarzoni Diaw, Thomas Balenghien

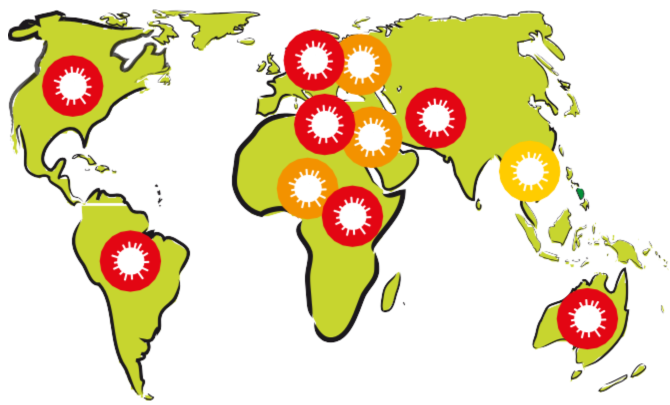
Focus on three *Flaviviruses* transmitted by mosquitoes of the genus *Culex*

Culex pipiens, a mosquito common in Europe, is a vector of several arboviruses, such as West Nile virus, Usutu and Japanese encephalitis.
© F. Thiaucourt, CIRAD.

The West Nile fever, Usutu and Japanese encephalitis viruses belong to the same virus family as dengue, yellow fever, and Zika: *Flaviviruses*.

Diseases		Reservoirs	Transmission
West Nile fever	>	Horses - Birds	**Direct** (main mode of transmission in humans): through contact with infected tissue from diseased animals **Indirect** (main mode of transmission in animals): through the intermediary of at least six genera of mosquitoes, including *Aedes* and *Culex*
Usutu	>	Wild birds	
Japanese encephalitis	>	Pigs - Birds	

Distribution



West Nile fever, worldwide progression

In metropolitan France, an epidemic was reported in 1962-1963 in the Camargue. Having been forgotten for decades and relegated to the rank of "exotic" diseases, West Nile fever is now back in the news as a health issue in many Mediterranean countries. The year 2018 was marked by an unprecedented epidemic at the European level, with more than 2 000 human cases reported and 187 deaths.

West Nile fever is the arbovirus – a virus transmitted by hematophagous arthropods (mosquitoes, ticks, etc.) – with the widest geographical spread: the disease is present in all continents, even as far as Siberia. West Nile fever is particularly virulent in raptors and corvids. In the United States, any increased mortality in crows is thus considered as an indicator of high circulation of the disease.

Of African origin, the virus is regularly introduced into Europe by wild migratory birds. At CIRAD, several scientists are studying the circulation of this disease within populations of mosquitoes and wild animals.

In-depth genetic analyses

Since the virus is very difficult to detect, the teams of researchers often need to trap several thousand mosquitoes in order to identify it. The scientists then conduct two types of analyses on the mosquitoes caught: specific analyses (specifically aimed at the West Nile fever virus), and non-targeted metagenomic analyses (which observe the whole spectrum of viruses carried by mosquitoes).

This second, more comprehensive type of analysis has already revealed the circulation of viruses that were previously unknown and have recently been associated with severe neurological disorders in France (see Usutu, next page). Through these studies, the researchers hope to discover a virus that only infects mosquitoes and is harmful to arboviruses, in other words the viruses transmitted by hematophagous arthropods, such as the West Nile fever virus.

Expertise
Serafín Gutiérrez

ARBOSUD (2018-2021; France, Burkina Faso)

ARBOSUD studies the interactions between arboviruses, mosquito vectors and the environment. Financed by the University of Montpellier, the project has several study areas in Burkina Faso and France. Every year in the Camargue and the Occitanie region in France, scientists from CIRAD regularly trap mosquitoes and collect fluid samples from animals. This data ensures better understanding of environmental determinants, and therefore of the epidemiological risk.

Usutu, an African virus emerging in Europe

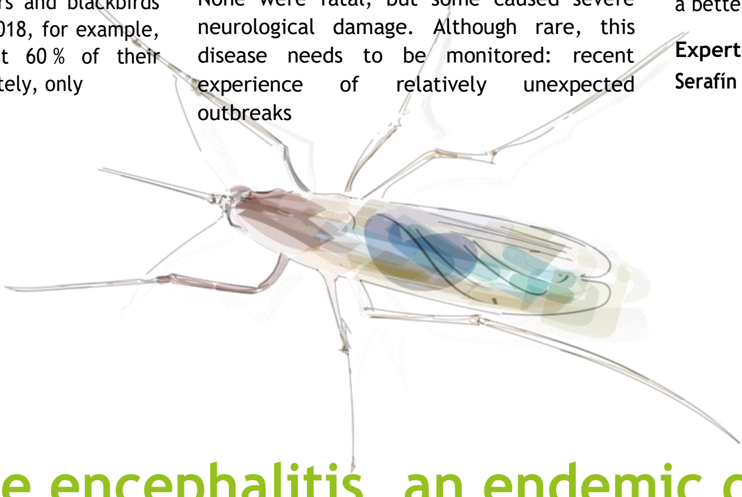
The Usutu virus was first detected in France in 2015. From June to September, scientists identified it at several sites in mosquitoes of the species *Culex pipiens*, which is common in France, and with high prevalence rates (more than one in 10 mosquitoes). In 2016, two strains of the virus emerged in Europe. One caused a human case in Montpellier, and the other led to high bird mortality. Cases in humans are often asymptomatic, but can sometimes cause a fever, skin rashes, encephalitis or meningoencephalitis, and partial facial paralysis.

The zoo in Montpellier is an open-air laboratory for teams from CIRAD and the University of Montpellier, who study the circulation of Usutu and West Nile fever between the mosquitoes and animals found there.
© Y. Sanguine, CIRAD.

The ecology of Usutu is similar to that of the West Nile fever virus. It arrives in Europe with migratory birds, and circulates between animals via the mosquito *Culex pipiens*. Since 2015, teams from CIRAD have been closely monitoring the evolution of this virus in France. Every year, they trap mosquitoes and look for the virus. In particular, the scientists work closely with the zoo in Montpellier, and monitor the circulation of the virus there in mosquitoes, birds and captive mammals.

The Usutu virus is capable of infecting more than 50 species of birds, belonging to more than 20 different bird families. Raptors and blackbirds are particularly affected. In 2018, for example, some parts of Germany lost 60 % of their blackbird populations. Fortunately, only 28 cases of human infection by Usutu have been reported in Europe in the last 10 years. None were fatal, but some caused severe neurological damage. Although rare, this disease needs to be monitored: recent experience of relatively unexpected outbreaks of other arboviruses, such as Chikungunya and Zika, shows that the scientific community needs a better understanding of this virus.

Expertise
Serafín Gutiérrez



Japanese encephalitis, an endemic disease in Asia that could spread to other parts of the world

Despite the existence of a vaccine, Japanese encephalitis is still the leading cause of encephalitis in Southeast Asia. Its transmission is endemic in 24 countries, representing more than 3 billion people at risk, or almost half of the world's population.

The virus that causes Japanese encephalitis is transmitted to humans by mosquitoes of the genus *Culex*, which are found in wetlands and rice paddies, and are typically associated with rural areas. However, the virus also circulates in peri-urban areas, and could well spread further. Between 1997 and 2000, RNA from the virus was detected in samples from wild birds in Italy. In 2017, an indigenous Japanese encephalitis case in a human was reported in Angola.

CIRAD is working to identify the geographical areas with climate conditions favourable to both hosts and vectors. New research is attempting to assess the risks of dissemination and endemisation, especially in the Indian Ocean, a part of the world that has close air and sea links with Asia. Finally, scientists from CIRAD also hope to improve understanding of how the disease functions and is transmitted to animals and humans. In particular, in a study conducted in Cambodia, researchers discovered that dogs are particularly exposed to the disease. Their proximity to humans can therefore make them a sentinel species that is useful in assessing the exposure of human populations to the virus.

Expertise
Julien Cappelle

Antibiotic resistance: a global threat

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In September 2016, the United Nations recognised the issue of antibiotic resistance as a global threat to health and human development. According to WHO, antibiotic resistance could cause almost 10 million deaths per year by 2050, and could slow the production of food of animal origin by 3 to 8 % every year.

Teams at CIRAD are working to better understand the mechanisms involved in the development and spread of these "super bacteria" in livestock farming and aquaculture. Depending on the region, they focus on the surveillance of antibiotic use, the emergence of resistant bacteria, awareness raising for local people about these health risks and, finally, the development of alternatives to antibiotics.

An active surveillance network in the Indian Ocean

Under the aegis of the Indian Ocean Commission, and in the framework of the SEGA One Health Network, teams from CIRAD working in the Indian Ocean islands have set up surveillance of antibiotic resistance, where the inappropriate use of antibiotics in farms can result in an increase in this resistance. Between 2016 and 2020, the scientists thus collected samples from more than 300 cattle, pig and poultry farms. The data showed high levels of resistance in chickens and pigs. The presence of resistant bacteria is thought to be associated with the therapeutic use of antibiotics, the presence of domestic animals on farms and recurrent visits from other farmers. The research also highlighted the key role of water quality, as well as the appropriate implementation of cleaning and biosecurity measures, in the fight against bacteria. Further to the application of these measures in Réunion, the situation is improving significantly.

The highest rates of resistance to antibiotics were recorded in pig farms in Madagascar, with high risks of bacterial exchange due to the close proximity between humans and animals. © V. Porphyre, CIRAD

What is antibiotic resistance?

Antibiotics are regularly used in livestock farming and aquaculture to fight bacterial diseases and to promote animal growth in some farms. This widespread use contributes to the development of antibiotic-resistant bacteria in both humans and animals. This is known as antibiotic resistance.

Awareness raising activities for farmers and veterinarians in Southeast Asia

In Southeast Asia, analysis of a multitude of data from several different countries in the region has shown that the recent increase in the standard of living has resulted in substantial growth in demand for animal protein, which has intensified production along with the use of antibiotics. The outcome is that antibiotic resistance has significantly increased there, made worse by unregulated sales networks for antibiotics, insufficient surveillance of their use and a lack of appropriate legal frameworks.

In Vietnam, intensive farms are attempting to reduce antibiotic use.
© V. Porphyre, CIRAD

CIRAD is trying to counter this trend by coordinating training and awareness raising activities for local actors (farmers, veterinarians, etc.). In partnership with FAO, local partners (veterinary services and universities) and AVSF, guidelines on improving biosecurity in farms and ensuring better use of antibiotics are distributed to farmers during training workshops. The scientists are also studying recent practice changes among farmers towards reduced antibiotic use. In Vietnam, for example, there is growing public interest in high quality food. Motivated by increasingly demanding consumers, some farmers are rethinking their modes of production. In order to understand the obstacles and drivers of such practice changes, as well as the legal organisation of the new certification schemes, the teams from CIRAD are conducting field studies, and collecting information from farmers, actors in the pharmaceutical sector and local decision-makers. The goal is to codevelop effective strategies to reduce antibiotic use, and to draw national recommendations from these.

ROADMAP (2019-2023; Europe, Mozambique, Vietnam)

This project, based in nine European countries as well as Mozambique and Vietnam, is aimed at understanding the use of antibiotics in animal health. Farmers, veterinarians drug manufacturers, health authorities, etc.: the practices of different actors are put under the microscope in order to imagine a more rational use of these antimicrobials, which will ultimately help to limit the risk of antibiotic resistance. The ROADMAP project has received 6 million euros of funding from the European Union H2020 programme.

Alternatives to antibiotics in aquaculture

CIRAD is working to develop alternatives to antibiotic use, especially in aquaculture. For several years, the aquaculture sector has been growing steadily, mainly in Asia. But this intensification of production has been accompanied by the excessive use of antibiotics, which are too often misused.

In order to promote more sustainable aquaculture, scientists from CIRAD and IRD are working within the ISEM research unit to study the effects of plants in strengthening the immunity of fish and their resistance to disease. Some local plants are known for their antibacterial and immunostimulant properties, and can for example inhibit the virulence of pathogenic bacteria in fish. An ethnobotanical study conducted among fish farmers on the island of Java in Indonesia thus identified 18 plant species with therapeutic applications used in farms. ISEM showed, for example, that the use of ground leaves of *Litsea cubeba*, a small tree in the family *Lauraceae*, has biological effects on the common carp (*Cyprinus carpio*, the dominant species in world fish production, at around 4 million tonnes per year), especially on growth, non-specific immunity and survival.

These plants, deriving from plant biodiversity and traditionally used by fish farmers, are therefore interesting alternatives for ecological intensification in fish farming systems and disease prevention in aquaculture. This work on the identification of alternatives to antibiotics also continues in the Indian Ocean, using the rich biodiversity in the area.

Does global warming foster antibiotic resistance?

In aquaculture the shift towards production practices that are less dependent on antibiotics is urgently required. A study published in 2020 by scientists from IRD and CIRAD establishes for the first time the linkage between global warming and increased risks of antibiotic resistance in aquaculture. Their findings show that global warming encourages the development of pathogenic bacteria, and therefore the emergence of diseases in fish farms. This increased mortality leads farmers to use more and more antibiotics, thereby driving the emergence of resistant bacteria. But the propagation of resistant bacteria, or the transmission of their resistance genes to other non-resistant species capable of infecting humans or animals, could cause diseases that are difficult to treat in these hosts.

Aquaculture is the agricultural sector that has grown the most in recent years. The misuse of antibiotics is common in fish farms. © L. Dabbadie, CIRAD.

How can we improve health for all? Can we prevent rather than cure? Questions/answers with our experts

1 > What are the linkages between environmental degradation, biodiversity loss and the emergence of infectious diseases in animals and humans?

The majority of new infectious diseases in humans originate in animals, especially wild animals. Understanding the interactions between wild animals, domestic animals and humans helps to better manage the risks of disease outbreaks.

Julien Cappelle, health ecologist

"Deforesting to develop agriculture and livestock farming means that local communities come into contact with the microbial cycles found in the major forest biomes"

Julien Capelle releases a bat fitted with a GPS tracker. © N. Furey, FFI

"There has never been such a high density of humans and domestic animals on the planet. Consequently, contacts with wild animals occur more frequently. The intensification of livestock farming and of human activities, in areas with high biodiversity, accelerates these contacts between wild and domestic animals, and increases the risk of new disease outbreaks.

Deforestation, especially in the intertropical zones, where there is a high level of biological diversity and the societies are still very vulnerable, fosters such outbreaks. Deforesting to develop agriculture and livestock farming means that the local communities come into contact with wild animals, and therefore with the microbial cycles found in the major forest biomes.

One of the keys to better understanding these transmission dynamics and avoiding them lies in the ecology of wild animals. For example, several studies show that there is a linkage between the reproductive cycle of animals and the circulation of pathogens. This information is essential to determine at which times of the year contacts with certain animals carry the highest risk.

Serge Morand, health ecologist

"Growth in livestock numbers throughout the world directly impacts wildlife and increases the number of epidemics in humans and domestic animals"

© K. Chaisiri

"There is a linkage between the increase in the number of epidemics, the loss of biodiversity and growth in livestock numbers.

Several studies show that there is a correlation between the increase in the number of epidemics reported in humans in each country (16 994 epidemics for 254 infectious diseases between 1960 and 2019) and local biodiversity loss. This means that the emergence of epidemics is a worrying marker for species conservation, and illustrates the death throes of biodiversity.

However, contrary to what could be believed, the epidemic risk does not decrease with the disappearance of species: on the contrary, it is relayed by the increase in livestock numbers. This is a second finding, confirmed by scientific research, which shows that growth in livestock numbers throughout the world directly impacts wildlife and increases the number of epidemics in humans and domestic animals.

This finding calls for thought to be given to the role of livestock and its growth in the world. A new approach, incorporating the cultural values associated with animals, is needed when thinking about the common role of wild and domestic animals in our society. This is a crucial shift, if we truly want to reduce health risks and protect biodiversity.

Another issue that is becoming a concern is the breeding of wild animals, a practice that is growing in Southeast Asia. Some species of ricefield rats, for example, are being bred, as they are popular for their meat and provide a source of additional income. But these farms are run in poor sanitary and ethical conditions, and do not have the necessary veterinary monitoring. The rodents are stressed by this type of environment, which weakens their immune response, and they are in contact with other animals as well as with the humans that handle them. The risks of pathogen spillover and of infectious disease outbreaks are therefore high in these farms."

2 > At what points are human-animal contacts close and do they carry risks of disease transmission?

Close contacts between humans and animals increase the risk of pathogen exchange. Livestock farmers, abattoir workers, hunters, and bushmeat consumers can all be exposed if basic health precautions are not taken. This is the case in some countries in Southeast Asia and Africa.

Véronique Chevalier, veterinary epidemiologist, coordinator of the ZooCov project

"We are working to develop a framework for the early detection of viral transmission from wild animals to humans"

© A. Tran, CIRAD

"The health crisis caused by SARS-CoV-2 has shown that the wildlife trade and wild animal meat consumption can play a role in the transmission of pathogens from animals to humans. In some places, wild meat, also known as bushmeat, is an integral part of local diets, and has been for generations.

In recent years, however, and particularly in Southeast Asia, there has been an increase in wild meat consumption. But with this growing demand comes the intensification of hunting and the bushmeat trade.

In 2020, CIRAD launched an international project, ZooCov, which is aimed at developing a flexible, integrated system for early detection of the transmission of betacoronaviruses between wild animals and humans. At two sites in Cambodia, we study the main trade chains for wild species, as well as practices and perceptions concerning wild meat consumption. We also quantify the presence and diversity of these viruses in wild meat, and seek to identify the vectors of animal infection and human exposure. By comparing this information, our goal is to develop a methodological framework for the early detection of viral transmission from wild animals to humans, which can be extended to other situations."

Sébastien Le Bel, veterinarian, CIRAD's coordinator for the Sustainable Wildlife Management (SWM) programme

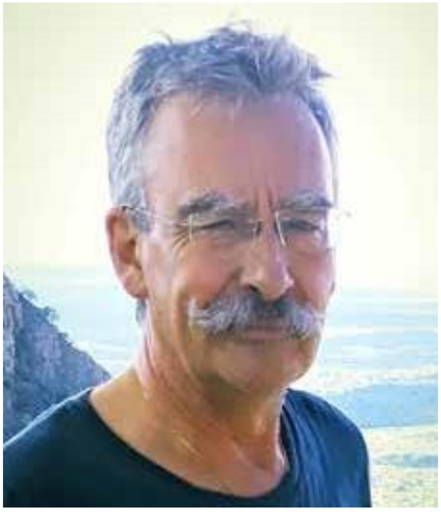
"We encourage sustainable hunting in accordance with health regulations"

"The consumption of bushmeat is a custom in some communities. It is essential to their diet when they have no access to other sources of protein. But high-risk practices exist, especially illegal hunting of wildlife and the preparation of this meat with no regard for health standards. These two activities are central to the transmission of pathogens between wild animals and humans.

Within the SWM programme, we contribute to the conservation of wildlife resources, and encourage sustainable hunting and fishing practices, in accordance with health recommendations to limit the risks of infection and the spread of disease. By formalising the bushmeat trade, we aim to accentuate visibility and control, to enable surveillance and to reduce health risks.

This implies strengthening management capacities in indigenous and rural communities, through the promotion of healthy and sustainable wild meat supply chains, and the revision of legal and regulatory frameworks.

We operate in many areas, with very different social and ecological contexts: Chad, Democratic Republic of the Congo, Gabon, Guyana, Madagascar, Mali, Papua New Guinea, Republic of the Congo, Senegal, Sudan, Zambia and Zimbabwe. We test sustainable governance and management models, in close collaboration with the authorities, national universities and local actors. This unprecedented geographical coverage is associated with diverse activities, such as support for public conservation policies, agricultural job creation, women's empowerment, and the protection of indigenous peoples' rights. This all makes this project a real model, faced with the ever more pressing ecological and economic needs of the poorest populations."



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Find out more
https://www.swm-programme.info/

3 > Can we prevent or monitor the emergence or re-emergence of diseases?

Understanding the causes of disease emergence is the key to better preventing them. But this requires effective surveillance systems capable of connecting the different actors concerned.

Renaud Lancelot, veterinary epidemiologist, coordinator of the MOOD project

"Through MOOD, we aim to improve global health surveillance capacities"

© CIRAD

"In 2020, CIRAD, along with 25 partners from a dozen European countries and the United States, launched a new project to strengthen the health surveillance system in Europe: MOOD. Through this project, we aim to improve European and global health surveillance, with a focus on exotic or emerging diseases with pandemic potential.

From the beginning of the project, the COVID-19 pandemic redirected a significant part of the MOOD project's activities towards fighting this disease. We therefore immediately implemented the innovation process underpinning the project: assessing the needs of users (human and veterinary public health agencies), prioritising research activities in response to these needs, and accompanying agencies in implementing the findings of research. A number of teams from MOOD thus responded to requests from their national agencies and the European Centre for Disease Prevention and Control (ECDC) in Stockholm: the production of standardised data sets for epidemiological analyses, reports on control scenarios, the risks of introduction and spread of new variants, etc. We conducted an initial review of these actions during a workshop organised with the researchers and agencies in December 2020.

At the same time, we conducted a needs assessment survey concerning epidemic surveillance, among the 10 public and veterinary health agencies that are partners of MOOD. The findings were presented and discussed with the agencies and researchers involved in MOOD, helping to refine their research.

The project is innovative: it aims to bridge the gap between fields that have too long remained focused on their own respective approaches. But communities of microbial or parasitic agents, and also the common exposure of their hosts to changing environmental or socio-economic conditions, creates close linkages between human health, the health of domestic and wild animals, and that of ecosystems. One of the goals of MOOD is to align the visions and objectives of the public health and veterinary health services in terms of the surveillance of diseases common to animals and humans, focusing on specific examples such as the surveillance of avian influenza, certain tick-borne infections, and West Nile fever. This is a big step towards the implementation of a "One Health" approach.

Our activities also look at indicators of outbreaks, whether direct or indirect. These include, for example, data from social networks or online news articles reacting to the emergence of an unknown disease. This data mining process, conducted for online articles with the PADI-web online platform developed by CIRAD, can prove critical for the early detection of outbreaks. Finally, we work to produce risk maps using modelling tools, but also, and especially, validated, standardised, secure and sustainable data sources.

Beyond the technological aspects, the main goal of MOOD is to build networks between all of the actors involved in epidemiological surveillance in order to ensure comprehensive, active and robust health surveillance at the continental level. Through its mandate, CIRAD strives in particular to share these innovations with its partners in the global South."

In the context of MOOD, the PADI-web platform detected the first signs of the emergence of COVID-19.
© M-I. Peyre, CIRAD

MOOD (2020-2024; European Union)

Developed in the framework of the EU Horizon 2020 programme, MOOD has a budget of 40 million euros and brings together 25 partners from 12 EU countries. This four-year project is aimed at improving European health surveillance, with a focus on exotic or emerging diseases. The goal is to build new tools for surveillance, control and information sharing between the different actors involved in public and veterinary health in Europe. Research will be conducted in France, Serbia, Finland, Italy, and Spain, and the results will be disseminated in all of the EU countries.

CIRAD was chosen to coordinate MOOD, since it can draw on its expertise in tropical diseases, but also its online surveillance of animal diseases (PADI-web), and finally its networking capacities, which have already been tested in the Caribbean and the Indian Ocean.

© CIRAD

Mathieu Roche, computer science researcher, specialising in data mining

"PADI-web, an animal disease surveillance platform used by the French Global Health Surveillance unit and the EU MOOD project"

"For several years, CIRAD has been developing an animal health surveillance platform, PADI-web. This online platform processes hundreds of Google News articles every day. African swine fever, avian influenza, Schmallenberg virus, etc., but also new diseases such as coronavirus: we monitor all diseases associated with animal health. Our goal with PADI-web is to supplement official health surveillance sources with unofficial information.

The online articles that our platform processes are taken from Google News. The tool translates all languages into English: these articles therefore come from all over the world.

This information is not derived from official data, and some articles only mention symptoms. The goal of PADI-web is to sort and organise all of this unofficial information, which could otherwise be overlooked.

PADI-web searches for the names of diseases, host animals, symptoms, dates, places, as well as a list of keywords, such as "epidemic", virus", or "alert". Through these searches, we are sometimes able to detect disease outbreaks before they are officially declared, or to detect the onset of a disease even before it is named, simply from descriptions of its symptoms.

We also collect crucial complementary information, such as vaccination campaigns or control measures.

PADI-web currently includes more than 200 000 online articles and is used by the Global Health Surveillance unit (VSI) of the French Epidemiological Surveillance Platform for Animal Health (ESA). Coordinated by CIRAD, the goal of the VSI is to detect and monitor any potential health risks for the French territory. To this end, we use both official data and unofficial data, especially those collected through PADI-web."

François Roger, veterinarian and epidemiologist

"Surveillance systems need to be co-developed at all scales, from the local to the international, and must be well coordinated"

© E. Bru, CIRAD

"To implement effective local surveillance systems, it is essential to acknowledge and to draw on the active participation of all actors: public authorities, patients, farmers, health professionals, intermediary bodies, local elites, etc. This is crucial if we want to co-develop surveillance systems that are tailored to local needs.

Participatory methods are new in the field of epidemiology and are proving successful locally, in both the South and the North. These approaches effectively supplement traditional surveillance systems. At CIRAD, we also build on other information, which is often unused, such as data on biodiversity, climate, land-use change, etc.

We also draw on informal sources, using for example digital surveillance, as the PADI-web platform does.

Finally, in order for information to circulate correctly, it is essential to connect regional health networks and to build a global mechanism with a "One Health" approach. CIRAD thus works jointly to develop local, regional and international surveillance instruments. We build these surveillance systems in partnership with local actors, doctors, veterinarians, farmers, etc., as well as with international agencies such as the World Health Organization (WHO), the World Organisation for Animal Health (OIE) and the Food and Agriculture Organization of the United Nations (FAO).

These surveillance systems are implemented at different scales, and we are trying to improve their coordination. This is the case of the PREZODE initiative." (See following page).

Marisa Peyre in the field, in Ghana, conducting participatory surveys. © CIRAD

Nathalie Vachiery, microbiologist, and Marisa Peyre, epidemiologist, specialising in surveillance systems and joint leader of the PREZODE initiative for CIRAD

"With PREZODE, our goal is prevention, early detection and rapid response to risks of pandemics of animal origin"

"PREZODE was launched by three French research institutes – INRAE, CIRAD and IRD – in association with several dozen public and private research organisations, from more than 50 countries, and international organisations such as WHO, OIE, FAO and UNEP. It is a new approach on an unprecedented scale, led by scientific research, to build appropriate solutions in a participatory manner with the individuals exposed to health risks on the front line, especially people in the global South. The goal is thus to strengthen international collaboration on outbreak prevention and rapid response to the first signs of outbreaks.

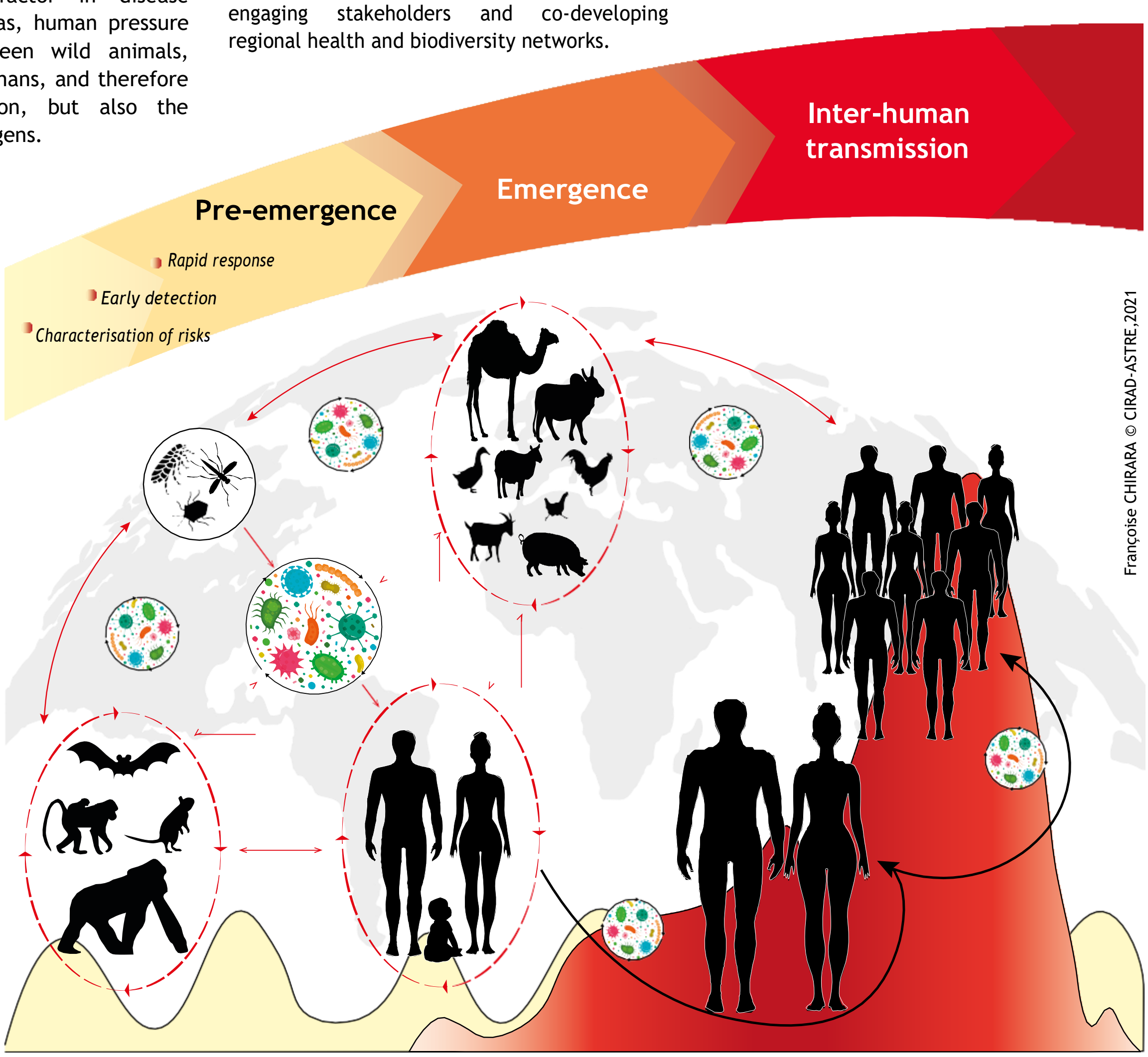
Rather than reacting to outbreaks, they must be avoided. But to avoid outbreaks, the human footprint on biodiversity must be reduced. Biodiversity loss in areas with high biodiversity is a significant risk factor in disease emergence. In these areas, human pressure increases contacts between wild animals, domestic animals and humans, and therefore the risks of transmission, but also the circulation of some pathogens.

To avoid pandemics, it is essential to react rapidly to the first signs of outbreaks. Rapid action is needed at the source when the event occurs, in order to avoid species jumps and the spread of the disease. To achieve this, warning systems need to be co-developed with local actors. To be able to react rapidly, reliable data is also needed, hence the importance of involving actors on the front line. To ensure prevention actions are conducted and that warning systems function, they must be understood and accepted, and all those concerned need to understand their role and their responsibility.

PREZODE is based on five pillars: assessing zoonotic risks; reducing these risks (prevention strategies); ensuring early detection and assessing the socioeconomic impacts of surveillance strategies; developing an international zoonotic risk monitoring system; engaging stakeholders and co-developing regional health and biodiversity networks.

The goal of the initiative is thus to build socio-ecosystems that are adapted and resilient, reducing the risks of zoonotic outbreaks while enhancing biodiversity and reducing poverty and food insecurity.

PREZODE is intended to connect and complete numerous ongoing projects and programmes. The initiative is based on existing networks of partners in research and in the field. The joint efforts of researchers, local communities and decision-makers to define appropriate solutions should lead to a reduction in the main risk factors in zoonotic outbreaks, the co-development of policies integrating human and animal health and biodiversity, the establishment of real-time One Health surveillance systems, and the consolidation of public-private partnerships and the science-society-policy dialogue.



4 > How can "parasite" pressure be reduced? Can a disease be eradicated?

Eradicating a viral disease requires vaccination campaigns and also, in the case of vector-borne diseases, vector population control. Such action often takes more than 10 years. At present, it is considered that only two viruses, smallpox and rinderpest, have been successfully eradicated in the world.

Annelise Tran, modeller

"To conduct effective vaccination campaigns and to reduce costs, we develop risk maps to target the priority areas for vaccination"

© V. Porphyre, CIRAD

"Spatial modelling is used to build maps of the risk of disease introduction, spread and emergence. We use different types of information for this. First, laboratory data on pathogens or vectors enable us to compile statistics, for example on the incubation period of a virus, or the vector competence of a species of mosquitoes. Second, field data, such as population densities of animals or insects, the potential areas of contact between species, etc. Climate data can also be used: rainfall and daily temperature have a significant impact on mosquito populations.

We enter all of this information into a programme that then builds the maps. These maps show the areas and times where the risk of transmission is highest, and where, for example, vaccination is a priority. These simulations are very robust thanks to all the data collected. This type of map can be used, for example, to organise vaccination campaigns for animals, where vaccination on a large scale would require considerable financial and human resources. By pinpointing priority areas, we radically reduce the costs while improving effectiveness. According to the same principle, we also develop maps to predict the development by geographical area of populations of insect vectors, such as mosquitoes, in order to identify the priority areas for vector control.

For vector-borne diseases, and when vaccination proves difficult or impossible, the goal is to attack vector populations: mosquitoes, ticks or tsetse flies in the case of sleeping sickness or animal trypanosomiasis. New targeted and environmentally-friendly techniques are now used to reduce their populations locally, taking them below the threshold for disease transmission."

Thierry Baldet and Jérémy Bouyer, entomologists

"Trying to eradicate a vector-borne disease globally without a vaccine is unrealistic; vector populations need to be controlled at the local or regional scale"

Jérémy Bouyer collecting *Aedes aegypti* larvae in a Pandanus, Saint Joseph. © CIRAD

"The eradication of a harmful species means its complete disappearance worldwide. For vector-borne diseases, which are transmitted by arthropods such as mosquitoes or tsetse flies, this would require the complete disappearance of certain species. This is both unrealistic and undesirable. Rather than eradication, the goal should to eliminate or control vector populations at the local or regional scale, particularly in areas of high risk for human or animal populations. In Senegal, for example, research conducted by CIRAD in partnership with several local actors, including ISRA, has enabled the elimination of populations of tsetse flies, which are vectors of animal trypanosomiasis in the Niayes region around Dakar.

Eliminating a species from a territory is not without risk: the void left can serve as an ecological niche for another species, which could potentially be just as harmful to human populations. In Réunion, for example, if the main vector of dengue, the mosquito *Aedes albopictus*, were to disappear further to vector control campaigns, it is very likely that the mosquito *Aedes aegypti* would take its place. But this mosquito is also an excellent vector of dengue.

In Réunion, CIRAD proposes an improved – or boosted – version of the sterile insect technique (SIT) for populations of *Aedes aegypti* mosquitoes, which are currently confined to very specific areas, such as ravines in the western and southern parts of the island. The first sterile male mosquitoes treated with a biocide will shortly be released by drone in the municipality of Saint Joseph, in agreement with local people and officials.

The goal is to show that a targeted population of this species can be eliminated locally, before turning to *Aedes albopictus*, which will be targeted in the second phase, in order to avoid niche replacement, cited as a potential risk by several French expert committees."

The sterile insect technique (SIT): a biological vector control method

The sterile insect technique (SIT) is considered as a biological control method. Its main advantage is that it is totally species specific. Sterile males only mate with their female counterparts of the same species (in mosquitoes, the males do not bite). The other advantage is that the lifespan of these sterile males is limited, making it possible to perfectly control the duration and scope of the control campaign. Finally, SIT does not result in insecticide resistance in the insects targeted. Boosted SIT is based on treating sterile males prior to their release with a biocide that specifically contaminates wild females during mating, in addition to the sterilising effect.

5 > How can health be improved for all people?

Some of today's health problems (zoonoses, antibiotic resistance, environmental pollution, etc.) are linked to our agricultural production systems. By acknowledging that human activities impact the world as a whole, and therefore that humans and nature are indissociable, it becomes possible to imagine new solutions tailored to local contexts. This is the goal of the Healthy Territories project coordinated by CIRAD.

Aurélie Binot in the field, Guiers Lake, Senegal. © CIRAD

Aurélie Binot and Raphaël Duboz, specialists in integrated approaches to health, coordinators of the Healthy Territories project

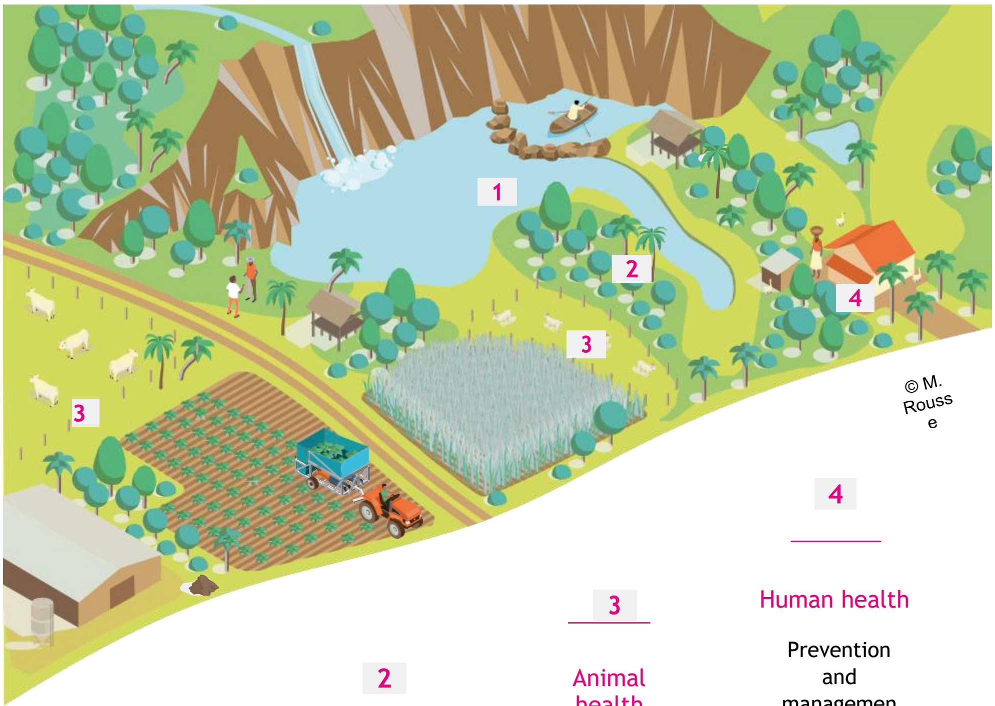
"Agreeing between sectors about what makes a healthy territory"

"The notion of the health of a territory goes beyond environmental, plant, animal and human health. For a territory to have long-term local development and social peace, it is necessary to consider overall health, but also the health quality of agricultural products. In the context of the Healthy Territories project, which will begin in 2021 at several sites in Senegal, Benin, Laos and Cambodia, we will focus on agroecology. This production system can be adapted to the different territories, guaranteeing the sustainability of agricultural production and protecting the health of the territory in all its dimensions.

But the first stage consists in defining what exactly is meant by health: local actors may not all agree on what they mean by "health", and the challenge is to ensure they reach a consensus on a common and shared definition.

In Senegal, for example, in the Lake Guiers region, the agricultural practices of sugarcane companies may compete with livestock farmers or organic vegetable growers. The former consider that they contribute to the health of the territory because they are a strong employer in an inland area, and provide health services for their employees. But they use pesticides, which could contaminate water and soils, posing a health risk to humans and their animals, as well as to crops.

The first thing to establish is therefore a dialogue between sectors that are not accustomed to exchanging ideas. To do so, the Healthy Territories project will set up living labs in the different study areas. Living labs are forums for discussion that represent all of the viewpoints of the actors in a territory. They will bring together actors who would never meet otherwise, and who will learn to make choices together based on shared experiments."



1 Environmental health

Prevention and management of environmental risks (pollution, etc.)

Balance in biogeochemical cycles

Natural biodiversity

2 Plant health

Prevention and sustainable management of plant pests

Adequate plant nutrition

Agro-biodiversity and balance of populations

3 Animal health

Prevention and management of animal diseases

Adequate animal nutrition

Genetic diversity of herds

4 Human health

Prevention and management of human diseases (hygiene, education)
Food security and nutrition

Social diversity

© Franck Dunouau

Conclusion

Michel Eddi, President Managing Director of CIRAD

"The epidemics we face compel us to rethink our modes of agricultural production and food consumption"

"In the face of the epidemic crises that strike humans and animals, we know that the consequences are serious for all countries: fatalities, job losses and business closures, along with an increase in social inequalities. These epidemics should make us think about our relationship with the living world and about ways to build more resilient health systems that are able to anticipate future crises by managing the risks of epidemic outbreaks more effectively and inclusively. This is the essence of the new PREZODE initiative, which aims to build the frameworks for action and the tools needed to improve prevention by detecting disease outbreaks as early as possible, but also to avoid them by better managing biodiversity at the interfaces between natural habitats and human societies. This initiative gives substance to the commitment by CIRAD, INRAE and IRD to develop international partnerships in these areas, in particular with the least developed countries. PREZODE is guided by the "One Health" approach.

Indeed, it is clear that ecosystem, animal and human health are all interlinked, and that agriculture and food are central to their interactions. Our health is impacted by what we eat; it depends on the health of the environment and the sustainable management of biodiversity, based on appropriate agricultural and food systems. Production, food, health and biodiversity are permanently connected, and each component must be considered in terms of its interrelationships with the others.

Faced with the urgent need to feed a growing population by 2050, we could think that it is impossible to change our intensive production model. But in 2018, CIRAD and INRAE showed in a prospective study on land use (Agrimonde-Terra) that a "healthy" scenario is feasible. To achieve this, concerted action is needed between numerous actors, all committed to the ecological transition in agriculture, in particular with greater cooperation between producers and agri-food companies, civil society and governments. In an op-ed in Le Monde, the Director of INRAE and I thus called for the implementation of:

- Food and health policies to increase consumption of fruit, vegetables and legumes, a greater diversity of cereals, and less consumption of oil, sugar and animal products (with variations according to the regions of the world).
- Agricultural, environmental and climate policies encouraging the development of agroecological practices that reduce greenhouse gas emissions and environmental degradation.
- Development and planning policies conducive to the intensification of relations between rural and urban areas and which foster employment in rural areas.

> *"The goal is to achieve the agroecological transition of our agricultural production models, but also to transform our food systems."*

The goal is to change our modes of agricultural production and to ensure their agroecological transition, but also to transform our food systems. Current food systems are still far from ensuring food and nutritional security for all people, and access to food still varies greatly, despite the fact that globally, there is enough food available. These systems have a high environmental and climate footprint, and the way they function favours some actors over others. CIRAD is thus calling for systemic, far-reaching changes in food systems.

In the face of population growth, food security throughout the world depends on this, as does the protection of our environment, while tackling climate change and limiting health risks. We no longer have the choice: we need to act now, and to do so globally. The One Health concept will help us to meet these challenges. CIRAD, with all of its partners in the North and the South, has been working to achieve this for many years, and we now need to scale up this process."

One Health

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