People's Democratic Republic of Algeria

Ministry of Higher Education and Scientific Research

Institute of Veterinary Sciences- Blida

Saad Dahlab university -Blida 1-

Graduation Project for obtaining a

Veterinary Doctor Diploma

Application of geographic information system (GIS) and WEB GIS for monitoring and surveillance of animal diseases (case of FMD and PPR in Algeria)

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Year: 2019/2020

Acknowledgements

First, we would like to thank Almighty God, who has given us the strength and patience we need to do this work.

We thank all the members of the jury, in the top of them **Mr. OUCHENE Nassim** and **Ms. KHELIFI Nadjet-Amina**, for accepting to examinate this work.

We would like to express all our gratitude to my supervisor, **Mr. DAHMANI Ali** and our co-supervisor **Mr. BOUFENIZA Redouane Larbi**. I thank them for having supervised, guided, helped and advised me.

We also address our sincere thanks to all the professors, speakers and all the people who, through their words, writings, advice and criticism, have guided our reflections and agreed to meet with we and answer our questions during our research.

Dedication

I thank my dear parents**,** Ammar and Djouhra, who have always been there for me. I also thank my brothers Redouane, Hamza, and Ahmed, and my sisters Amel and Ghania for their encouragement. Also, a special thank to Roumaissa, Naila, Maissa, Dania, and Kawthar who have always been there for me.

I would like to thank Asma, Khadidja, Moufida, Wahiba and Maya, for their friendship, their unconditional support and their encouragement.

Finally, I thank all my family members and friends, especially the members of the scientific club IBN-EL BAYTAR whom I love so much, for their sincere friendship and trust, and to whom I owe my gratitude and my attachment.

To all these speakers, I offer my thanks, respect and gratitude.

BOUFENIZA Amira

Dedication

Dear parents, Nadji and Fatiha, thank you for always being there to lift me up and encourage me.

I offer my special thanks to my sisters Roumaissa, Noura, Belkisse; I really appreciate your help, this mean lot to me.

I dedicate for my lovely friends Maya, Khadidja, Amira ,Moufida, Hiba and all members of Ibn Baytar-club, who supported me in difficult time of my life as well as in time of joy.

Finally, for my family members and my workmates all I can say is thanks.

CHOURAK Asma

Abstract

The livestock sector is one of the most important agricultural sectors, particularly in developing countries. However, the subsistence of pastoral livestock is limited by the frequent presence of trade-sensitive diseases that can affect the economic aspect of any country. And one of those diseases are peste des petits ruminants (PPR) and foot-and-mouth disease (FMD) which are highly contagious diseases, that spread rapidly across local and international borders and have a serious impact on public health or the economy.

In recent years, the geographic information systems (GIS) used for a wide variety of purposes, in different fields among them in veterinary field. It represent an ideal platform for the convergence of specific disease information and analysis.

The study aimed to describes the evaluation and implementation of a spatial database that are directly or indirectly related to animal health in GIS and a web-GIS and the visualization of the spatio-temporal distribution of animal disease such as FMD and PPR in Algeria.

We have also created a model of a website « VETALGIS » (Veterinary Algerian GIS) in order to digitalize the veterinary sector and minimize the problem of lack of data, organize them and facilitate access to them. which will improve networking and communication between institutions responsible for livestock disease management.

A methodology has been adapted based on the classical steps of GIS; and performed using freely available Qgis 3.10, this methodology can be largely applied to touch different types of diseases.The results we obtained are maps and tables of Livestock population (Bovine, Ovine, Caprine) and there distribution in Algeria; Animal production; Distribution of FMD and PPR cases in Algeria and Kser El Boukhari region in Medea state.

GIS spatial analysis techniques have proven to be a useful tool that can support the decision-making process in planning, implementing and monitoring FMD and PPR control strategies in endemic and high-risk areas.

Keyword : Geographical information system (GIS), peste des petit ruminants , Foot and mouth diseases .

Résumé

Le secteur de l'élevage est l'un des secteurs agricoles les plus importants, en particulier dans les pays en développement. Toutefois, la subsistance du bétail pastoral est limitée par la présence fréquente de maladies sensibles au commerce qui peuvent affecter l'aspect économique de tout pays. L'une de ces maladies est la peste des petits ruminants (PPR) et la fièvre aphteuse, qui sont des maladies très contagieuses, qui se propagent rapidement au-delà des frontières locales et internationales et ont un impact sérieux sur la santé publique ou l'économie.

Ces dernières années, les systèmes d'information géographique (SIG) ont été utilisés à des fins très diverses, dans différents domaines, notamment dans le domaine vétérinaire. Ils représentent une plateforme idéale pour la convergence d'informations et d'analyses spécifiques sur les maladies.

L'étude visait à décrire l'évaluation et la mise en œuvre d'une base de données spatiales directement ou indirectement liée à la santé animale dans un SIG et un web-SIG et la visualisation de la distribution spatio-temporelle des maladies animales telles que la fièvre aphteuse et la peste des petits ruminants en Algérie.

Nous avons également créé un modèle de site web " VETALGIS " (système d'information géographique vétérinaire algérien) afin de numériser le secteur vétérinaire et de minimiser le problème du manque de données, de les organiser et d'en faciliter l'accès. Ce qui permettra d'améliorer la mise en réseau et la communication entre les institutions responsables de la gestion des maladies du bétail.

Une méthodologie a été adaptée, basée sur les étapes classiques de la mise en œuvre d'un SIG, et a été effectuées à l'aide de Qgis 3.10 librement disponible. Les résultats que nous avons obtenus sont sous forme de cartes et de tableaux de la répartition du cheptel, de la Production animale, des cas de fièvre aphteuse et de PPR en Algérie et au niveau de la region de Kser El Boukhari dans la wilaya de Medea.

Les techniques d'analyse spatiale des SIG se sont avérées être un outil utile qui peut soutenir le processus de prise de décision dans la planification, la mise en œuvre et le suivi des stratégies de lutte contre la fièvre aphteuse et la RDP dans les zones endémiques et à haut risque.

Mots-clés: Système d'information géographique (SIG); Peste des petits ruminants ; Fièvre aphteuse.

ملخص

تعد تربية المواشي من أهم القطاعات الزراعية خاصة في البلدان النامية، إلا أن هذا القطاع تعترضه مشاكل تحول دون الحفاظ على هذه الثروة، حيث أن عيش هذه الحيوانات محدود بفعل الأمراض المتكررة وأبرزها: طاعون المجترات الصغيرة ومرض الحمى القلاعية التي تعتبر شديدة العدوى، إذ تنتشر بسرعة عبر الحدود المحلية والدولية ولها تأثير خطير على الصحة العامة والاقتصاد.

خلال السنوات الأخيرة، تم استخدام نظم المعلومات الجغرافية لأغراض عدة في مجالات مختلفة من بينها مجال الطب البيطري، فهي تمثل منصة مثالية لجمع وتحليل معلومات مرض ما بما في ذلك المنشآت السكانية، الخدمات الاجتماعية والصحية المحيطة والبيئة الطبيعية.

هدفنا من خلال هذه الدراسة إلى تأسيس قاعدة بيانات مكانية مرتبطة بصحة الحيوان بشكل مباشر أو غير مباشر في نظام المعلومات الجغرافية ونظام المعلومات الجغرافية على شبكة الإنترنت وتقييم التوزيع المكاني والزماني للأمراض التي تمس الحيوان (الأمثلة المدروسة: الحمى القلاعية وطاعون المجترات الصغيرة في الجزائر). كما قمنا بإنشاء واقتراح نموذج لموقع الكتروني "VETALGIS"(نظم المعلومات الجغرافية البيطرية الجزائرية) من أجل رقمنه قطاع الطب البيطري وتقليل مشكلة نقص البيانات وتسهيل الوصول إليها بتنظيمها. فهو يجمع بين مختلف الشركاء (فلاحين، إدارة، طبيب بيطري) في منصة واحدة من شأنها تحسين التواصل بين المؤسسات المسؤولة عن إدارة أمراض الثروة الحيوانية.

تم تكييف منهجية بناءً على الخطوات الكلاسيكية لنظم المعلومات الجغرافية باستخدام برنامج Qgis المتاح مجانًا لتحليل الوضع الحالي، الحصول على البيانات ومعالجتها، كما يمكن توسيع تطبيق هذه المنهجية على مختلف الامراض الحيوانية. قمنا بتلخيص النتائج التي تحصلنا عليها في خرائط وجداول (توزيع الثروة والانتاج الحيواني توزيع حالات مرض الحمى القلاعية وطاعون المجترات الصغيرة في الجزائر عامة ومنطقة قصر البخاري بولاية المدية خاصة.

أثبتت تقنيات التحليل المكاني والزماني لنظام المعلومات الجغرافية أنها أداة مفيدة يمكن أن تدعم عملية صنع القرار في تخطيط وتنفيذ ورصد استراتيجيات مكافحة الحمى القلاعية وطاعون المجترات الصغيرة في المناطق الموبوءة والمعرضة للخطر.

الكلمات المفتاحية: نظام المعلومات الجغرافية (GIS); طاعون المجترات الصغيرة ; مرض الحمى القلاعية.

SOMMARY

List of tables

List of figures

List of abbreviations

PPR : Peste des petits ruminants**.**

FMD: Foot-and-mouth disease**.**

GIS: geographic information systems.

VETALGIS: Veterinary Algerian geographic information systems.

RNA: Ribonucleic acid.

SAT: South African Territories.

FMDV: Foot-and-mouth disease Virus.

ECF: East Coast Fever.

OIE: World Organisation for Animal Health.

VSD: Veterinary Services Direction.

PPRV : Peste des petits ruminant virus.

Kb: kilo bases.

Ksh: Kenyan shillings.

VS: veterinary Services.

CCPP: Contagious Caprine Pleuropneumoniae.

ORF: Contagious Ecthyma.

SGP: Sheep and Goat Pox.

PCR: polymerase chain reaction tests.

GPS: Global Positioning System.

DBMS: database management system

ID: common identifier.

QGIS: Quantum Geographic Information Systems.

GUI: Graphical User Interface.

GPL: General Public License .

GML: Geography Markup Language.

WFS: Web Feature Service.

WMS: Web Map Service.

SQL: Structured Query Language.

PNG: Portable Network Graphics.

GRASS: Geographic Resources Analysis Support System.

MADR: Ministry of Agriculture and Rural Development.

LAN: local area network.

OSM: Open Street Map.

MP: Milk Production.

CMP: Cow milk production.

Moy : Moyenne.

RMP : Red Meat Production.

Qs : Quintels (1 Qs= 100kg).

BMP: Bovine Meat Production.

OMP: Ovine Meat Production.

OV: Ovine.

BV: Bovine.

CP: Caprine.

Introduction

Introduction

The livestock sector is one of the most important agricultural sectors, particularly in developing countries. However, the subsistence of pastoral livestock is limited by the frequent presence of trade-sensitive diseases that can affect the economic aspect of any country. Which make their potential for infection a further challenge to control. and one of those diseases are peste des petits ruminants (PPR) and foot-and-mouth disease (FMD) (Amaral et al., 2016; Gitonga, 2015; Knight-Jones & Rushton, 2013; Paton et al., 2009).

In recent years, New and modern tools are therefore essential for monitoring and surveillance of these diseases (Mfmf et al., 2018). the geographic information systems (GIS) is one of those tools and which has been used for a wide variety of purposes, in different fields among them the veterinary medical sciences (Hay, 2000; TS & AW, 2017) especially in veterinary epidemiology (Rinaldi et al., 2006).

This paper describes the evaluation and implementation of a spatial database in GIS and a web-GIS application that allow the management of animal disease like FMD and PPR in Algeria, Also, visualization and analysis of data that are directly or indirectly related to animal health and its future projections in Algeria.

The study therefore aimed to demonstrate the distribution of FMD and PPR in Algeria and the utility of application of GIS/Web GIS techniques as tools that can be used in the planning, and implementation of disease monitoring and control programs in endemic and high-risk PPR and FMD areas in Algeria and as a decision support tool.

We have also created a model of a website «VETALGIS " (Veterinary Algerian GIS) that constitutes a platform that brings together all animal health dealers (administrative bodies - veterinarians - breeders) in order to digitalize the veterinary sector and minimize the problem of lack of data, organize them and facilitate access to them.

Problematic: How FMD and PPR disease are distributed in Algeria? How we can mapping this distribution ? What is the utility of using GIS/Web GIS for decision makers?

Chapter I

Foot and mouth disease

I. Foot and mouth disease

I.1 Definition

Foot-and-mouth disease (FMD) is a highly contagious disease. It affects cloven-hoofed animals (Grubman & Baxt, 2004) such as cattle, swine, sheep and goats, as well as many wildlife species (Paton et al., 2018; Weaver et al., 2013). The importance of FMD varies according to the type of production.

I.2 Virus characteristics

FMD Virus is an Aphtovirus caused by an RNA virus a single-stranded RNA virus belonging to the genus (FMDV) of the family Picornaviridae (Amaral et al., 2016; Garland & Donaldson, 1990; Paton et al., 2018). Serotypes have been serologically identified, including serotypes A, O, C, Asia 1, South African Territories (SAT) 1, SAT 2 and SAT 3, and each serotype comprises several subtypes (Bachrach, 1968; Ma et al., 2017) and within each serotype there are numerous strains (Pharo, 2002; van Regenmortel et al., 2000). Depending on the dose and the route of infection, the incubation period varies from 2 to 14 days (Gailiunas & Cottral, 1966; Knight-Jones et al., 2017) which explains the rising of successive waves of infection, which sometimes spill over into FMD- free regions (Diaz-San Segundo et al., 2017; Paton et al., 2018).

The FMDV replicates and evolves rapidly, making it possible to study transmission and selection at different scales: between cells and tissues (i.e. within the same animal), animals, farms and countries (Orton et al., 2013; Paton et al., 2018). Depending on conditions, the duration of persistence of FMDVs may be linked to their replication and cell-killing capacity (Paton et al., 2018; Sellers, 1971). It's reproduces in infected animals and is generally spread to susceptible animals by aerosol, via the respiratory tract (A. I. Donaldson, 1987). FMDV is excreted in milk, semen, urine, and feces (A. I. Donaldson, 1987; Hyde et al., 1975; Ma et al., 2017).

I.3 Transmission

Virus spread in endemic areas is characterized by frequent direct and indirect contact with animals. Incursions into FMD free countries may be spread by unlikely events such as fomites or wind-borne aerosols over long distances (A. Donaldson et al., 1982; Paton et al., 2018). In acute infection, transmission is facilitated by excretion of the virus from ruptured vesicles and in body excretions and secretions, including breath, milk and semen. Susceptible ruminants can become infected with very low doses of inhaled virus through direct contact with the breath of other acutely infected animals, or indirectly through resuspension of aerosols from contaminated materials (Alexandersen et al., 2003; Paton et al., 2018). Other infection routes, like ingestion or abrasions, involve a higher dose of virus. (Paton et al., 2018).

There is a rapid immune response to infection associated with the elimination of FMDV, but some ruminant hosts continue to harbor the virus, becoming carriers with low and decreasing levels of FMDV at specific nasopharyngeal epithelial sites (Paton et al., 2018; Stenfeldt et al., 2016), and associated lymphoid tissues (Juleff et al., 2008; Paton et al., 2018). For example, Co-infection studies in African buffalo identified the infectious virus and viral genomes for up to 185 and 400 days respectively in the lymphoid tissues of the head and neck, mainly in the germinal centers (Maree et al., 2016; Paton et al., 2018). Indirect transmission routes are notoriously difficult to quantify, but they are the main means of spread of the FMD virus in countries which effectively impose movement bans in the event of an outbreak (Orton et al., 2013; Paton et al., 2018).

I.4 Symptoms and lesions

Characteristically, vesicles develop, particularly in the epithelium around the mouth, feet and mammary glands (Paton et al., 2018). The most common symptoms in infected animals are fever, lameness and vesicles on the tongue, feet, muzzle and teats. Fever usually occurs after vesicular lesions (fig. 1 and 2). Severe lesions appear in areas under physical stress or trauma and viremia can be detected in most infected animals (Ma et al., 2017).

Figure 1. Ulcerative lesions of foot-and-mouth disease on the gum

(Chahnaz, 2019).

Figure 2. Ulcerative lesions of foot-and-mouth disease on the tongue

(Chahnaz, 2019).

I.5 Health animal impact

FMD impact is multi-faceted, with direct and indirect impacts, as well as visible and invisible losses, all of which can be substantial, hard to estimate and very variable (Knight-Jones et al., 2017; Knight-Jones & Rushton, 2013). The lethality rate is generally low, except for young animals, but productivity losses and control costs can be significant (Knight-Jones & Rushton, 2013; Paton et al., 2018). In adult animals, FMD does not cause high mortality, but it does cause weight loss, reduced milk production, loss of tensile strength, sterility and abortion in mothers. However, in young animals, mortality due to FMD can be high and the FMD virus can affect heart function (Brooksby, 1982). This requires that the dynamics of the herd be modeled to understand how the structure, productivity and efficiency of the livestock herd are affected by FMD (Knight-Jones et al., 2017).

I.6 Economic impact

FMD has no specific treatment because it is a viral disease. However, mortality rates can be reduced by using supportive treatment with drugs that will treat or prevent secondary bacterial or parasitic complications. Specifically, oxytetracycline or long-acting chlortetracycline are recommended to prevent secondary infections (FAO, 2015). Vaccination remains the most effective and cost-effective strategy to prevent or control FMD (FAO, 2015; Gitonga, 2015; OIE, 2013).

An understanding of the impact of diseases is necessary to guide livestock disease control policy. In fact, some FMD-endemic countries invest large sums of money in disease control, while others invest little or no investment at all. Political decisions are often taken without taking sufficient account of the economic impact of the disease and its control. This may be due to a lack of awareness of what is known about the impact of FMD in endemic countries, the absence of studies on the subject and the lack of guidance on how to assess it (Knight-Jones et al., 2017). An outbreak of FMD can lead to devastating economic losses for a considerable period of time (Ma et al., 2017), it can cause more than 1.5 billion dollars of losses per year in disease-free countries and regions (Knight-Jones & Rushton, 2013; Ma et al., 2017). Consequently, areas affected by foot-and-mouth disease are subject to trade embargoes and may not export animals or animal products to foot-and-mouth disease free countries (Ma et al., 2017). Therefore, the enforcement of control measures is costly and can have extensive negative effects. Also restrictions on the movement of livestock and trade bans are damaging the profits of farmers and the economy as a whole (Knight-Jones et al., 2017). In the other hand, large and small milk-producing livestock farms are generally the most affected (Knight-Jones et al., 2017). For example, in Southern Sudan, annual losses resulting from reduced milk production and FMD mortality have been estimated at US$25 per head of livestock in the population. (Barasa et al., 2008). In Pakistan, milk losses for 60 days were estimated at $100 per affected lactating cow (Ferrari et al., 2014; Muriuki, 2011).

Turkey, estimated direct costs range from US$152 per affected dairy heifer to US$294 for an affected lactating dairy cow, and about US$200 per affected animal for beef cattle (Knight-Jones et al., 2017; Şentürk & Yalcin, 2008). The impact at the population level can be high in the groups, where FMD is prevalent, particularly for those who have a dependence on FMD-affected products like milk (pastoralists and commercial dairy farmers), and where national economies depend on access to FMD -free export markets. (Knight-Jones et al., 2017).

Local markets in FMD endemic countries also close during FMD epidemics and limits the flow of animals and products (Knight-Jones et al., 2017; Yusuf, 2008). The impact on food security is difficult to assess and could result in several different consequences of FMD, including losses in milk production, physical condition, mortality and traction force (Barasa et al., 2008; Casey et al., 2014; Jemberu et al., 2014; Knight-Jones et al., 2017; Nampanya et al., 2016).

The impact of FMD on trade is particularly important for those in a position to export bovine meat (Knight-Jones et al., 2016, 2017). while civil unrest disrupts disease and border controls and changes the flow of animals, people and trade (Di Nardo et al., 2011; Hall et al., 2013; Paton et al., 2018).

I.7 Disease prophylaxis and treatments

The control of FMD requires decades of regional collaboration with effective veterinary services and large participation of farmers (Knight-Jones et al., 2017).

The strategy applied to control and eradicate FMD is based on activities and actions aimed at identifying the presence or certifying the absence of an animal disease in a given geographical zone, with special attention to border regions.

Currently, the prevention and control policy implemented consists of a combination of immunization and culling to a large extent. those operations focus on the farms which are most likely to contain infected or diseased animals.

In addition, mass vaccination of all cattle, and eventually sheep and goats, every six months may be unfeasible in developing countries with a weak infrastructure and many small farms (Knight-Jones, 2015; Knight-Jones et al., 2016, 2017).

Vaccination with killed vaccines is widely used in the fieldwork, but the immunity induced is short-lived and is serotype- and sometimes strain-specific (Diaz-San Segundo et al., 2017).

I. 8 Geographical distribution

The disease is concentrated in Africa and Asia, with the global distribution reflecting both poverty and livestock density (Knight-Jones et al., 2017; Paton et al., 2018). The spread of FMD virus to higher scales (i.e. between holdings, countries or regions) is a complex process influenced by factors other than virus excretion and absorption (Paton et al., 2018). For example, long-distance aerial transmission of FMD virus depends on specific conditions of virus transfer and survival, which can now be predicted by models taking into account wind direction and strength, temperature, relative humidity and geographical topography (Gloster et al., 2010). Also, the movement of people, goods, animals and their products can contribute highly in FMD virus distribution (Paton et al., 2018). Due to tireless efforts, several developed countries have eliminated FMD and remain free of the disease, but FMD is still widespread in many developing countries (Ma et al., 2017).

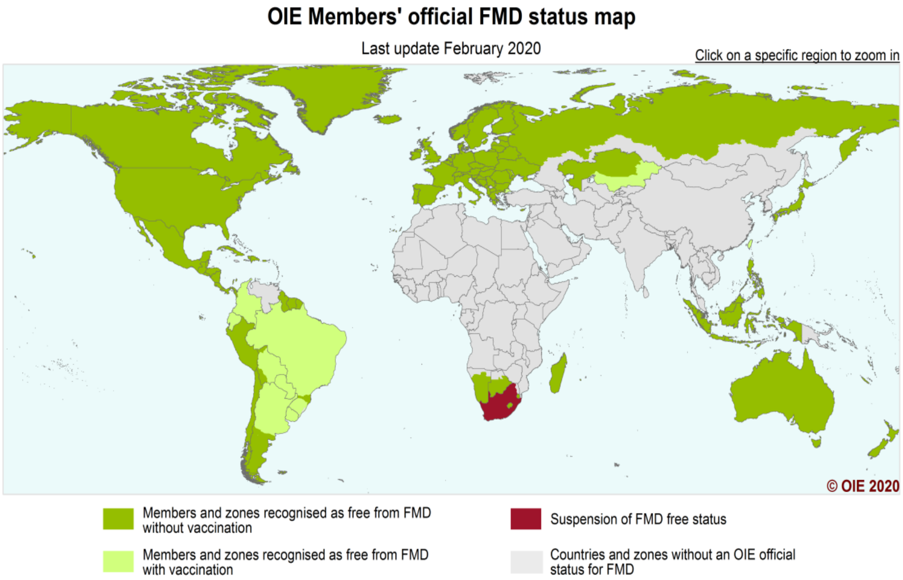

Figure 3. OIE Member's official FMD status map.

Modeling and field studies generally show a high incidence of FMD in endemic countries (fig. 3) (Knight-Jones et al., 2017).

I.9 FMD in Africa

According to a World Bank survey of African governments, FMD is the livestock disease with the third largest impact on poverty after ectoparasitosis and Newcastle disease (Gall & Leboucq, 2004). Nevertheless, another survey of national veterinary services in Africa, revealed that only 11 % of the countries listed FMD as the highest priority disease for smallholder farmers. However, FMD was ranked as a general priority by more countries than any other livestock disease, including zoonoses, although the position of FMD on the list of priorities varied (Grace et al., 2015; Knight-Jones et al., 2017).

A survey of Kenyan livestock farmers revealed that FMD was once again ranked as the livestock disease with the highest impact after East Coast Fever ("ECF") (Onono et al., 2013). Farmers in Borena, in Ethiopia, called FMD as the most important livestock disease. (Jibat et al., 2013; Knight-Jones et al., 2017).

I.10 Epidemiology

Numerous FMD seroprevalence surveys have been carried out in endemic countries. These surveys usually involve samples of cattle aged between 6 and 24 months, so that seropositivity reflects infection at some point in their lives. However, the exact period of risk of infection is unknown, making it difficult to establish an exact incidence rate. In addition, because animals acquire immunity over time, the incidence will be lower in older cattle (Knight-Jones et al., 2017). The inability to assess this burden at the population level may be exacerbated by under-reporting diseases, as is the case for influenza and many foodborne diseases in humans (Knight-Jones et al., 2017; Mead et al., 1999; Reed et al., 2015). FMD epidemics are generally under-reported in endemic countries. Based on the few cohort studies or studies evaluating underreporting that have been carried out in endemic areas, a high incidence of FMD is not uncommon (Bronsvoort et al., 2003; Casey et al., 2014; Knight-Jones et al., 2017; McLaws, 2012). Traditional extensive livestock systems often rely on local and remote community pastures. Herds are in direct contact with several other herds every day, resulting in high levels of disease transmission (Bronsvoort et al., 2003). Herds that are sedentary and do not use communal pastures are at lower risk. Incidence is expected to be lower when stocking densities are low and there is less contact between animals and groups, as there is less opportunity for transmission (Knight-Jones et al., 2017).

I.11 Diagnostic

Antibodies against non-structural proteins are usually evaluated. These antibodies are produced after FMD virus infection and after vaccination against FMD, unless a purified vaccine has been used. Few countries use purified vaccines (e.g. Turkey), so the proportion of seropositive animals may include vaccinated animals that have not been infected. Nevertheless the levels of vaccination are in general low in cattle and negligible in small ruminants (Knight-Jones et al., 2017).

Chapter II

Peste des petits Ruminants

(PPR)

II. Peste des Petits Ruminants (PPR)

II.1 Definition

Peste des petits ruminants (PPR), also known as sheep and goat plague, is a highly infectious viral disease affecting small ruminants such as goats and sheep, with goats being more susceptible (Gitonga, 2015; OIE, 2013). Some wild ruminants such as gemsbok, gazelle, springbuck, impala and wild goats are also susceptible (Gitonga, 2015; OIE, 2013; Pastoret et al., 2006).

According to the Office international des épizooties, "PPR is a notifiable disease", which means that it is listed by the OIE and OIE member countries as one of the diseases whose detection or suspicion must be brought to the attention of the veterinary authority, in Algeria it is VSD "Direction des Services Veterinaries".

It is a highly contagious disease, that spread rapidly across local and international borders and have a serious impact on public health or the economy. Also, based on the fact that the disease directly affects the livelihoods of more than 330 million people in Africa, the Middle East and Asia it was declared a target disease for eradication which requires effective layouts that's ensure its elimination or at least decrease its spread as quickly and cost-effectively as possible. (FAO, 2015; Gitonga, 2015; OIE, 2013).

II.2 Virus characteristics

Peste des petits ruminant's virus or PPRV is a virus belonging to the genus Morbillivirus of the family Paramyxoviridae (Gitonga, 2015). That does not infect humans but significantly disrupts the livelihoods of livestock farmers (FAO, 2015; Gitonga, 2015). The PPRV is genetically grouped into four lineages (I, II, III, and IV). PPRV has a lipoprotein membrane enveloping a core of the ribonucleic acid (RNA) genome. The genome is a single-stranded, negative polarity RNA approximately 16 kilo bases (kb) long. The PPRV genes are segmented into six transcription units which encode two non-structural proteins (V, C) and six structural proteins: the surface glycoproteins which comprise the fusion (F) and hemagglutinin (H) proteins, the template protein (M), the nucleoprotein (N) and the phosphoprotein (P) which forms the association of the polymerase complex with the large protein (L) (Gitonga, 2015). Based on the F and N gene sequences analyses which reflect geographical origin Lineage I and II are commonly reported in West Africa

, lineage III in Eastern Africa except for Sudan that has lineage IV as well lineage III (Banyard et al., 2010; Libeau et al., 2014; OIE, 2013)

II.3 Transmission

Animals infected with PPRV lose large amounts of the virus in their secretions and excretions such as ocular and nasal discharges as well as the cough and faeces secretions. The main route of transmission is close contact between animals, including inhalation of fine droplets, which are released when animals cough and sneeze. Fomites, such as litter, feed and water, also serve as a means of disease transmission, but only for a short period of time because PPRV does not survive in the environment (Gitonga, 2015; Kumar et al., 2014; OIE, 2013; Pastoret et al., 2006).

II.4 Symptoms and lesions

Clinically, PPR is characterized by sudden onset of depression, fever, mouth sores and necrotic stomatitis, bilateral eye and nasal discharge (fig. 4 and 5), gastroenteritis, pneumonia, malodorous diarrhea which cause a severe dehydration that often leads to death (Gitonga, 2015; OIE, 2013; Pastoret et al., 2006).

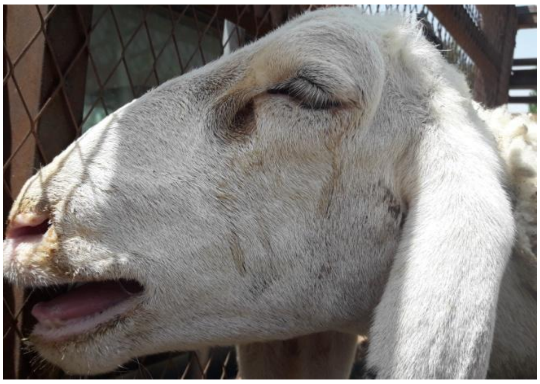

Figure 4. Salivation and eye scabs (Chahnaz, 2019).

Figure 5. Tearing and mouth breathing (Chahnaz, 2019).

The appearance of clinical signs vary according to the type of PPRV lineage, the affected species, the breed and the immune status of the animal. Although there is only one serotype, there are several different forms of the disease (acute, peracute and subacute) that determine the severity of the disease. The most common course of the disease is the acute form, which is characterised by an incubation period of 3 to 4 days followed by a sudden rise in body temperature to 41 degrees Celsius (°C). The hair, especially in short-haired breeds, stands up and gives the animals a puffy appearance. Affected animals are very depressed and refuse to eat or move, preferring to stay still or sleep. The febrile stage is quickly followed by animals with bilateral clear water discharge from the eyes and nostrils (Gitonga, 2015; Radostits & Gay, 2000). Discharge changes in 1 or 2 days to become thick and yellow due to a secondary bacterial infection (CouaCy-Hymann, 2013; Kumar et al., 2014). Discharges wet hair below eyes and around the muzzle resulting in matting together of eyelids and difficulty in breathing. Death is usually the result of bronchopneumonia or dehydration due to severe diarrhea (Gitonga, 2015; Maina et al., 2015; OIE, 2013).

II.5 Economic impact

The contribution of small ruminants to livelihoods and pastoral economies is limited by frequent disease outbreaks. Diseases of small ruminants increase the vulnerability of livestock keepers in three main ways:

* They cause the death of livestock assets;

* They reduce productivity;

* And they limit market access.

Current estimates indicate that annual direct global losses due to PPR are between US$1.2 billion and US$1.7 billion. In addition, it is estimated that annual global expenditures for immunization against PPR are in the range of US$ 270-380 million (FAO, 2015; Gitonga, 2015). Present global estimates indicate that PPR outbreaks in endemic countries result in an annual loss of nearly US$2 billion (Gitonga, 2015). For example: In Kenyan government incurs an annual cost of nearly one billion Kenyan shillings (Ksh) due to the costs of PPR vaccination and revenue lost during quarantine and trade bans (GOK, 2008). Also, a recent socio-economic study in Turkana revealed that losses due to the PPR epidemic from 2006 to 2008 were previously underestimated and are now estimated at USD 19.1 million, with kids and lamb mortality constituting the largest economic losses, estimated at USD 16.8 million (Gitonga, 2015; Simon M Kihu, Gitao, et al., 2015).

II.6 Risk factors

It's very important to determine risks factors in the aim of improving the management of PPR disease in small ruminant pastoral production systems (Gitonga, 2015).

The five risk factors significantly associated with PPR seropositivity were as follows:

- Age of animals, adult animals were more likely to be seropositive for PPR than animals aged 6 to 12 months;
- Geographic location of herds in the study areas, which determined the accessibility of veterinary service;
- the size of goat herds, animals from large herds were more likely to be PPR positive because of the likelihood that their owners would invest in preventive vaccines against PPR ;
- Impact of PPR outbreaks in the past ;
- PPR vaccination status (Gitonga, 2015).

II.7 Disease prophylaxis and treatments

PPR has no specific treatment because it is a viral disease. However, mortality rates can be reduced by using supportive treatment with drugs that will treat or prevent secondary bacterial or parasitic complications. Specifically, oxytetracycline or long-acting chlortetracycline are recommended to prevent secondary lung infections as well as the use of anthelmintics to reduce the worm load (FAO, 2015). Vaccination remains the most effective and cost-effective strategy to prevent or control PPR (FAO, 2015; Gitonga, 2015; OIE, 2013).

Control of PPR in endemic areas is mainly achieved through the use of a live attenuated vaccine that was developed after isolation of PPR virus (Diallo et al., 1989; Gitonga, 2015). The live PPR vaccine gives protection against all 4 virus lines and confers permanent immunity to vaccinated animals after a single subcutaneous dose (Kumar et al., 2014). The vaccine is also safe and can be administered to pregnant animals at any stage of gestation (CouaCy-Hymann, 2013). Vaccination is still the most effective method of controlling PPR (Gitonga, 2015).

Mothers' vaccination induces the production of antibodies against the PPR virus, which are passively transferred to the young by the colostrum. These colossal antibodies protect the young during the first five months of life (CouaCy-Hymann, 2013). However, the PPR vaccine has limited thermal stability, as studies indicate that after reconstitution, the vaccine has a half-life of 2-6 hours when kept at 37°C (Kumar et al., 2014).

The overall PPR strategy aims at eradicating PPR by integrating 3 key components:

Component 1: is PPR eradication that should take a country 15 years or less to achieve. Component 2: is building the capacity of veterinary Services (VS) to ensure quality services and component 3: is aimed at combining PPR control with the control of other important small ruminant diseases such as Sheep and Goat Pox (SGP), Contagious Caprine Pleuropneumoniae (CCPP), contagious ecthyma (ORF), pasteurellosis and brucellosis (FAO, 2015; Gitonga, 2015)

The other method is active surveillance, which involves a considerable investment in both human and financial resources because it aims to acquire biological evidence of immune development through serological testing (Catley et al., 2012; Simon M Kihu, Gachohi, et al., 2015). However, the active surveillance method requires a reliable animal identification system to ensure that the vaccinated animals are the same as those sampled for the post-vaccination serological survey (FAO, 2015).

Nevertheless, measures to control vaccination had limited impact and failed to prevent periodic PPR outbreaks (Gitonga, 2015; Simon M Kihu, Gachohi, et al., 2015). Eradication of the PPR virus is possible when the virus exists as a single serotype, and the available live attenuated vaccines are effective and confer lifetime immunity against all 4 lines after a single subcutaneous dose (FAO, 2015).

In addition, an absence of evidence of a carrier state or the existence of a domestic or wild reservoir outside the small ruminant population will also facilitate quick control efforts (Elsawalhy et al., 2010; FAO, 2013; Gitonga, 2015).

II.8 Geographical distribution

PPR was first seen in Ivory Coast in 1942 by Gargadennec and Lalanne, who described PPR as a disease in goats and sheep that had similar clinical signs to rinderpest but was not transmitted to in contact cattle (Pastoret et al., 2006). For many years, the disease was confined to West African countries, but in 1972, a disease affecting goats and resembling rinderpest was reported in Sudan and was later confirmed as PPR (Banyard et al., 2010). Some reports indicate that the disease is endemic across 70 countries in Africa; in Central Africa (Banyard et al., 2010), Eastern Africa (Ferrari et al., 2014; Kabaka et al., 2012; S M Kihu et al., 2012; Muse et al., 2012); the Middle East and in Asian countries of India, Nepal, Bangladesh, Pakistan and Afghanistan (Banyard et al., 2010; Gitonga, 2015).

II.9 Epidemiology

The PPR virus has an incubation period of 3 to 10 days and infections result in high morbidity rates of 90% and mortality rates of 70% in susceptible small ruminants herds (Gitonga, 2015; Radostits & Gay, 2000). The wide range of mortality rates in PPR infections is due to different levels of immune development. Studies have shown that the physical condition of the animal, the species (sheep or goat), breed and age of the animal, as well as the occurrence of concomitant bacterial or parasitic infections, play a role in susceptibility to PPR (Gitonga, 2015; Pastoret et al., 2006). In naïve populations, which means animals that have not been exposed to nature or vaccination, the mortality rate can approach 90%, with deaths occurring within 5 to 10 days of infection. However, in endemic areas, mortality rates vary from 30 to 70 % and are limited to young and juvenile animals.

II.10 Diagnostic

The diagnosis of PPR is tentatively established by clinical observation of the characteristic symptoms of laboured breathing, eye and nasal discharge, diarrhoea and the presence of mouth sores. Preliminary diagnosis can also be made by the post mortem lesions of stomatitis, enteritis and pneumonia (Gitonga, 2015; Kenya, 2014; OIE, 2013). Since the clinical signs are similar to those of other economically important diseases of sheep and goats, Confirmation of PPR virus is important. Confirmatory diagnosis requires laboratory tests that primarily identify viral proteins or antibodies raised against the PPR virus. in PPR outbreaks, samples must be collected and depends on the stage of the outbreak. At the onset of outbreaks, samples must be collected from animals with fever, which are in the acute phase of the disease (OIE, 2013). It is recommended that samples must be taken from acutely affected live animals include swabs of conjunctival secretions, nasal secretions and oral and rectal mucosa. Blood treated with anticoagulants may also be collected for the identification of viral antigens using polymerase chain reaction tests (PCR) and for hematological investigation.

Hematology results will allow the diagnosis of PPR virus because viral infections lead to a significant reduction in circulating white blood cells, especially lymphocytes; while bacterial infections lead to an increase in white blood cells, especially neutrophils (Gitonga, 2015; Wood & Quiroz-Rocha, 2010). The use of whole blood for the detection of antibodies will not be useful in the first days of the outbreaks because it takes 2-3 weeks for the animals to develop immunity to produce an antibody response (OIE, 2013) . However, some studies have shown that traces of antibodies to PPR virus can be detected from day 7 after experimental infections and that antibodies continue to increase until day 28 after infection and begin to decrease and stabilize after day 30 after infection (Gitonga, 2015; Maina et al., 2015).

Samples from dead animals must not be taken from fresh carcasses more than 6 hours after death. The PPR virus has a very fragile ribonucleic acid (RNA) genome that disintegrates rapidly in dead tissue or in the presence of secondary bacterial infections. This means that decomposed necrotic tissue and purulent ocular discharge can compromise the quality of PPR virus RNA and is therefore not suitable for PCR testing (OIE, 2013). Necrotic samples should be collected aseptically from two or three animals. The target tissues to be collected include the lungs, spleen and intestinal mucosa as well as the mesenteric and bronchial lymph nodes. All tissue samples must be refrigerated on ice or in liquid nitrogen and transported to the laboratory on the same day if possible. Organ samples taken for histopathology should be placed in 10% neutral buffered formalin (CouaCy-Hymann, 2013; Dundon et al., 2014; Gitonga, 2015; Maina et al., 2015).

In the later stages of the epidemic, after 2 to 3 weeks, blood can be collected for serological diagnosis to demonstrate the presence of antibodies raised against the PPR virus (Kenya, 2014; OIE, 2013). However, it should be noted that there is no serological test to distinguish vaccinated animals from those that have recovered from natural infection. This requires that all serological samples must always be accompanied by an appropriate history of the PPR vaccination status of the sampled animals. (Simon M Kihu, Gachohi, et al., 2015; OIE, 2013).

All those confirmatory tests to detect and identify PPR virus antigen/nucleic acid or antibodies are available and approved by OIE (Gitonga, 2015; OIE, 2013).

Chapter III

Geographic Information System (GIS)

III. Geographic Information System (GIS)

III.1 Definition

Broadly speaking, a GIS is a platform composed of hardware (computer material), software, data and people (operator and users) that form a fundamental system and universally applicable set of value-added tools used for the capture, storage, verification, integration, manipulation, analysis and display of geographically referenced data from various sources such as remote sensing and GPS systems (Bailey, 1994; Burrough, 1986; Gabriele Garnero & Ingrid Vigna, 2018; Mfmf et al., 2018; TS & AW, 2017; Vinodhkumar et al., 2016).

Any information from any discipline that is linked and coded geographic locations , such as country, province, district or latitude/longitude coordinates, is capable to be stored and manipulated in the GIS (Norstrøm, 2001). The advantage of using a GIS rather than a traditional database management system (DBMS) is that GIS combines computerized mapping technology with database management systems (DBMS), in which spatial data sets can be summarized visually through the graphical environment (Kuldeep et al., 2013; Norstrøm, 2001; Pfeiffer et al., 2008; TS & AW, 2017). So the power of GIS lies in their ability to link different information in a spatial framework and to reach a conclusion about this spatial relationship that cannot be seen if one looks at the information independently (without a spatial framework) (Vinodhkumar et al., 2016).

III.2 Components of a GIS

GIS displays the georeferenced data as thematic layers one by one or on top of each other. Digital maps are stored in GIS in two basic formats: vector and/or raster while data are stored in attributes (Sanson et al., 1991).

III.2.1 Raster

In raster-based systems, spatial information is aggregated by superimposing a grid over the area of interest; the user can specify the dimensions of the grid pattern, which can be viewed as a picture of the area. Grid or raster-based systems are convenient for storing and manipulating regional-type features, and information from remotely sensed image data is extracted efficiently (Vinodhkumar et al., 2016).

III.2.2 vector

In vector systems, geographic features are represented by points, arcs and polygons. Points are unique locations as x, y coordinates; arcs (lines) are usually made up of their respective line segments (vectors); polygons are areas bounded by arcs (closed line) (Gitonga, 2015; Kuldeep et al., 2013; Sanson et al., 1991; Vinodhkumar et al., 2016). On the other hand, the resolution of vector systems is naturally very high. Once all the desired data has been entered into a GIS system, it can be combined to produce a wide variety of individual maps, depending on the data layers included. Any GIS data layer can be added to or subtracted from the same map.

III.2.3 Attribute

Attributes can be any element related to the map but not part of it and can be associated either with each individual cell or with groups of cells that are homogeneous with respect to a particular feature (e.g. land use, animal density, etc.), usually stored in tables that can be linked to the geographic data by a common identifier (ID) (Kuldeep et al., 2013; Sanson et al., 1991; Vinodhkumar et al., 2016).

III.3 GIS Features

GIS features can be summarized in the following (5A rules):

- **Abstraction:** which consists in proposing a model of the real world in order to be able to study it;
- **Acquisition:** which concerns the ability to integrate different types of spatial data such as digital maps, aerial photographs, satellite images and Global Positioning System (GPS) data, and the associated tabular database (e.g. "attributes" or characteristics of geographic features) (TS & AW, 2017). (Kuldeep et al., 2013; Norstrøm, 2001);
- **Archiving:** which consists of storing or disseminating data, selling or sharing it, and integrating it into a large number of different software applications;
- **Display:** This refers to the representation of geographic data on a 2D or 3D screen;

- **Analysis:** GIS allows the cross-referencing of information from different sources to produce new knowledge.

III.4 Operations of GIS

Among the most important operations offered by GIS are the overlaying and data output.

III.4.1 Overlaying

The main strength of a GIS is its ability to overlay. Data are stored in separate layers that consist of attribute data such as climate data, human or animal population and disease incidence data (Sanson et al., 1991). The different layers can then be overlaid/merged to create composite maps that allow users to interactively query data sets, analyze spatial information, and present the results of these operations in maps, tables, and organized data sets (Gitonga, 2015; Kuldeep et al., 2013; Lichoti et al., 2014; McKenzie, 1999; Prattley, 2009),which also makes it possible to calculate new values for places and to identify and display places that correspond to specific features (Bhatt & Joshi, 2012; TS & AW, 2017).

III.4.2 Data output

The data output component of the GIS allows you to view the data or information in the form of maps, tables, diagrams, etc. Results can be provided in paper, electronic or electronic format. Maps and tables are usually produced permanently in hard copy format. The production of the hard copy takes more time and requires more expensive equipment. However, it is permanent and easy to transport and display. A large map can be displayed at any level of detail by increasing the physical size of the output. Output in electronic format, on the other hand, consists of computer-compatible files. They are used to transfer data to another computer system, either for further analysis or to produce a paper output at a remote location (Aronoff, 1989; Margonari et al., 2006; TS & AW, 2017).

III.5 GIS in veterinary sciences

As mentioned above GIS can be applied for many disciplines and many fields and veterinary field is taking its share as well.

The application of GIS in veterinary science is increasing daily. Initially, people used it primarily for vector-borne diseases, now it is being applied to the mapping of infectious and non-infectious diseases. It increases the efficiency of communication and brings significant added value to current routine data that are generally little considered for epidemiological or management purposes in veterinary medicine which make deficiencies in a surveillance system also become more evident (Esuruoso et al., 2005; TS & AW, 2017; Vinodhkumar et al., 2016).

GIS technology demonstrates the power and potential of spatial analysis capabilities to address important health issues at the international, national and local levels. There are many capabilities that make it ideal for the control of animal diseases. It can be used as a tool to store information and relate it to factors that are known to influence the spread of infectious diseases such as climate and other environmental factors, to fully explore the spatial and temporal clustering of disease and mortality events with precision (Mfmf et al., 2018; TS & AW, 2017; Ward & Carpenter, 2000).

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According to the different services provided by the GIS, its application in the veterinary field may cover different standards and levels which are usually branching off from each other. We can mention among them:

III.5.1 Disease mapping

The first step in any investigation of a disease outbreak is to map its spatial distribution in order to be able to assess the patterns present and generate hypotheses about the factors that might influence the observed pattern (Davis et al., 2014; Koocheki & Gliessman, 2005). Disease mapping can also makes it possible to communicate the results to a wider audience who may not have the technical background to understand the scientific terms and figures that indicate the burden and impact of diseases. (Christopher & Marusic, 2013; Jeffery et al., 2014; Koocheki & Gliessman, 2005; Pfeiffer et al., 2008; Thumbi et al., 2010).

Types of disease maps

Disease maps can be either quantitative or qualitative.

- **Qualitative disease maps:** indicating the location without specifying the quantity of disease.
- **Quantitative disease maps:** indicating the location with a specific disease burden (Vinodhkumar et al., 2016)

GIS can be used to produce maps of disease incidence, prevalence as well as mortality and morbidity at farms, regional or national levels, it can also visualize disease outbreaks, monitor newly infected or re-infected villages, identify high-risk populations. On the other hand, the representation of data in the form of a map help veterinarians in the field to plan their work in the current situation and veterinary authorities to manage a possible outbreak (Hussain et al., 2013; Koocheki & Gliessman, 2005; Kuldeep et al., 2013; Mfmf et al., 2018; Olabode et al., 2014; Premashthira, 2012; Vinodhkumar et al., 2016)

III.5.2 Epidemiological Investigation of Complex Diseases Problems

Among the exploratory methods for epidemiology and public health is the application of GIS. In veterinary epidemiology, GIS can be used in two fold:

- In a research-oriented environment to understand a disease by identification of risk factors, spatial modeling of the disease, and distribution and prevalence studies (what, when, who and where)

- To analyze the epidemic (why and how), and as a powerful tool for disease control and implementation of preventive measures i.e. emergency response, disease detection, operational optimization of the response, etc (TS & AW, 2017).

GIS has the capacity to combine geo-referenced data generated by global positioning systems (GPS) with ecological data and data from surveillance and management activities for the identification and mapping of environmental factors associated with low or high disease prevalence, making it particularly useful for disease surveillance and monitoring of ongoing control efforts (Norstrøm, 2001; TS & AW, 2017).

III.5.3 Abattoir Site Suitability Analysis

The impact of the slaughterhouse can manifest itself in the form of liquid waste (characterized by salinity of the effluent and bacterial contamination), airborne waste (mainly unpleasant odors), significant potential for transmission of animal diseases, noise, traffic congestion, attraction of animals (such as hyenas) and large birds, etc. Most of these environmental problems can be considerably reduced by appropriate siting of the slaughterhouse (TS & AW, 2017).

III.5.4 Recording and reporting disease information

Usually, when data are collected either systematically or through specially designed surveys, they are presented in tabular form, which can be used for analysis. Since disease information is often tending to be aggregated (individual herd information at the municipal or county level), the information loses some of its value. If information is mapped at the farm level, the value of the data is maintained, and small parts of an area can be viewed at the same time. However, reading and interpreting these data is often a laborious and time-consuming task and does not allow for easy decision making, also it is known that the human eye tends to pick up patterns or colors rather than just data (Mfmf et al., 2018; Paolino et al., 2005; TS & AW, 2017; Vinodhkumar et al., 2016).

III.5.5 GIS for planning disease control strategies

In disease control or eradication planning, the GIS has the possibility to perform an overlay analysis to find areas at high or low risk of disease that depend on geographical characteristics or geographically related conditions (Neighborhood Analysis). in addition, common source of contacts (e.g. common use of grassland or sources of purchase, etc.) can be visualized by GIS and buffer zones may also be created around other risk areas or point sources, such as roads where infected cattle have been taken or around markets. That could give an insight into the possibility of infectious disease transmission between herds and provide a simpler communication which mean that decisions can be made more quickly by non-technical policy makers (Gitonga, 2015; Kuldeep et al., 2013; Marsh et al., 1991; McGinn et al., 1997; Mfmf et al., 2018; Rogers, 1991; TS & AW, 2017; Vinodhkumar et al., 2016).

III.5.6 Clustering of diseases

The study of spatial and temporal groupings of diseases is potentially a powerful method for generating and testing hypotheses about the causes of disease, and provides a foundation for the epidemiological approach. Also the usefulness of space-time surveys is not limited to the epidemiology of infectious diseases; they can also be used in various fields such as better identification of livestock and the systematic recording of their location, health and production status offered by modern animal health surveillance systems (Vinodhkumar et al., 2016).

III.5.7 Modeling disease spread

In the simulation models, farm information such as herd size, type of production and spatial factors like distance from the source of the outbreak, population density and climatic conditions, vegetation and landscape have all been identified as risk factors for the spread of the modeled disease (Vinodhkumar et al., 2016).

III.5.8 Ecological analysis

Ecological analysis focuses on describing the relationships between the geographical distribution of diseases and environmental risk factors and analyzing them using statistical procedures (Kistemann et al., 2002; Miller et al., 2011; TS & AW, 2017; Vinodhkumar et al., 2016).

III.5.9 Evolution of disease outbreaks (dynamic maps)

When several features are drawn on the same map, it is possible to describe and explain the dynamics of the disease and modes of spread.

III.5.10 Correlation of disease trends with climatic and other predictions information

GIS can be used to correlate disease trends with, for example, climatic variations and other information such as entomological data that could be used for forecasting (Vinodhkumar et al., 2016).

III.6 Web GIS

The history of Internet GIS is linked to Internet mapping, which is developed in five distinct stages, differentiated by technological developments and the level of user interactivity. The first generation of Internet mapping consisted of a static map integrated as an animation file or link in a web page. Initially, digital maps were scanned copies of printed maps. However, researchers recognized that scanning a printed map document and publishing it as an image for electronic access via the World Wide Web resulted in a lower quality product. The maps had to be designed specifically for distribution via the Internet (Harrower et al., 1997).

Today, spatial databases work in synergy with GIS by providing data integrity and consistency checks, concurrent access, backup and recovery procedures, data query and visualization methods, authorization control, and efficient manipulation operations for spatial data (Djordjević-Kajan, 1997; Rigaux et al., 2003).

Internet GIS is particularly useful because it uses the distributed nature of the Internet to increase access to GIS tools through a user-friendly interface that has a positive impact on access to environmental data (Hoover, 2014), Internet GIS research has shown that this technology is user friendly and allows users to interact intuitively with environmental data.

Internet GIS technology is a tool that can disseminate animal disease information to well owners in an accessible and understandable manner.

Sharing data on the Internet can also be useful for publishing the consortium's data. QGIS2Web is a plugin developed for QGIS and freely downloadable, which allows transforming a project carried out by the software into a shareable map on the web. The consortium could use it to share maps of work in progress on its website (Gabriele Garnero & Ingrid Vigna, 2018).

Chapter IV

Materials and methods

IV. Materials and methods

IV.1 Literature Approach

Literature review and research was conducted by reviewing published articles, doctoral theses, reports and grey literature. Online search were used: ScienceDirect, Google scholar and Google web were searched for papers containing 'FMD' or 'foot and mouth disease' and PPR or 'peste des petits ruminants' 'GIS in veterinary sciences (Knight-Jones et al., 2017).

IV.2 Objective and approach

The study aimed to describes the evaluation and implementation of a spatial database that are directly or indirectly related to animal health in GIS and a web-GIS and the visualization of the spatio-temporal distribution of animal disease such as FMD and PPR in Algeria. it also aimed to show the utility of application of GIS/Web GIS techniques as tools that can be used in the planning, and implementation of disease monitoring and control programs in endemic and high-risk PPR and FMD areas in Algeria and as a decision support tool.

This should assist the user from data acquisition to decision making; thus, such a study promotes the dissemination and valorization of the research work.

In sum, the contributions of this GIS bring together the following approaches:

- Collecting data;
- ensuring the sustainability, integrity and consistency of the data;
- visualize the information relating to the results of the evaluation campaigns and the study areas;
- provide easy access to data;
- Simplify as much as possible the export of data to the statistical analysis software;
- development of thematic and synthesis maps;
- creation of new information.

IV.3 Study area

Representing the territory is necessary for being able to make any decisions, communicate with the exterior and supervise the evolutions caused by interventions (Godfrey, 2009).

The selection of areas to be included in the study was made intentionally and on the basis of available financial resources and the following criteria:

1. The area is classified as an endemic or high-risk area for PPR on the basis of DVS recordings and official disease reports (Elsawalhy et al., 2010; FAO, 2015; Gitao et al., 2014; Gok, 2015).
2. The inhabitants are pastoralists with high sheep and goat populations (KNBS, 2009).
3. Is an important route for small ruminant stocks to neighbouring countries (Aklilu, 2008). On the basis of the above criteria, we divided our study on two scales: Small scale and large scale. The large scale represent our whole country Algeria and for the small small scale the daïra of Kser El Boukhari was selected (Gitonga, 2015).

IV.3.1 Algeria

Since the division of Sudan in 2011, Algeria is the largest country of Africa with 2,381,741 square kilometers. It shares borders with Morocco, Tunisia, Libya, Niger, Mali, Mauretania and the Western Sahara.

Algeria consists of three main geographical zones, each with its own climate. In the north, the Mediterranean Sea dominates the fertile coastal plains that extend up to the Atlas Mountains. On the other side of the Atlas, the High Plains (Hauts Plateaux) form a semi-arid zone. The largest part (about 80 percent) of the country consists of the Sahara desert.

Algeria has an enormous agricultural potential and each zone is characterized by its own climate, vegetation and animal life (Fanack.com, 2020).
Livestock farming in Algeria is mainly based on sheep and goat livestock, followed by cattle livestock. The viability of this sector as a whole depends heavily on such factors as improvement of breeding methods, disease control, and imported feed.

IV.3.2 Kser El Boukhari

The region of Ksar El Boukhari, is administratively attached to the Wilaya of Medea. It is a plateau with an area of more than 3,288 km^2, located between the mountainous chain of the Tellian Atlas in the north and the high plains of M'sila and Djelfa in the South. The climate is of a semi-continental Mediterranean type, cold and humid in winter, temperate in spring and hot and dry in summer. In winter, the temperature drops below -5°C, while in summer it exceeds 45°C. Rainfall is irregular and annual precipitation does not exceed 350 mm. There are more than 2,300 herds in the region. It is the crossroads of two important sheep breeds in Algeria; Ouled Djellal in the South-East, Rembi in the South-West and to a lesser degree, the Berber breed in the North on the Atlas mountains Tellien (Yahiaoui et al., 2013).

IV.4 Materials used in the research

The materials used in this study include:

- A computer I.5;
- Software: Qantum GIS (version 3.10.5), Excel;
- Storage media (USB, hard drive... ect).

IV.4.1 Presentation and software choice

IV.4.1.1 Quantum GIS (QGIS)

Quantum GIS or "QGIS" is an open source geographic information system. Founded by Gary Sherman in May 2002 and established as a project on SourceForge in June of the same year. It is developed using the Qt toolkit and C++. This means that QGIS is fast and has a nice and easy to use graphical user interface (GUI). The name "Quantum GIS" has no special significance, except that it starts with a Q indicating that it uses the Qt library. The main purpose of QGIS is two-dimensional interactive visualization of spatial data. However, there are also features for editing vector data, analytical features (GRASS plugin) and a large number of extension modules (plugin). QGIS allows the user to open EXCEL, ACCESS files and work on ORACLE data, and handles a large number of vector and raster formats including PostGIS, GRASS, Shapefile, GML, WFS, GPX, WMS, GeoTiff, PNG, JPG and many others. It also supports on-the-fly re-projection for vector datasets using the PROJ4 library. Qgis has made GIS software (which is traditionally expensive proprietary software) a viable prospect for anyone with basic access to a personal computer.

Figure 6. Qgis openning software plateform.

Currently it runs on most Unix, Windows and MacOS platforms. QGIS is available under the GNU General Public License (GPL). Developing QGIS under this license means that the public can inspect and modify the source code, and guarantees that users will always have access to a free and openly modifiable GIS program (Gabriele Garnero & Ingrid Vigna, 2018; Project, 2020; SCOOP federation, 2006; Shekhar & Xiong, 2008; Trolltech, 2006).

IV.4.1.2 Microsoft Excel

The use of Excel software is required to export and edit the depth stations in Excel text format (CSV), necessary for their integration in QGIS.

Excel also offers the possibility to perform descriptive statistical operations such as selection, filtering, sorting by ascending or descending order, and the graphical presentation of data (Curves, Histograms, Clouds of points, etc).

IV.5 VETALGIS Web application

IV.5.1 Objective and preparation framework

VETALGIS (Veterinary Algerian GIS) web application is a digital and evolutionary platform, developed within the framework of a graduation project in veterinary sciences following a remarkable need in this field, where digitization and the speedy circulation of information has become indispensable and remains unsatisfactory in relation to current technological development.

Figure 7. VETALGIS Web application logo's.

The main objective of this platform is to bring together the various partners involved in the veterinary field in Algeria and all animal health dealers, namely administrative bodies - veterinarians, farmers, in order to ensure the following objectives:

- The advantages of this platform are as follows;
- Determine the spatial distribution of animals in relation to the agricultural potential (vegetation cover) and the socio climatic and economic aspect;
- Real-time monitoring of diseases and simplifying intervention and precautionary measures;
- To know the animal potential and their concentrations;
- Build a reliable and fast database;
- Bringing together the different partners (farmer, administration, veterinarian, laboratory) in a single platform;
- To know the needs and the gaps that can have in the cycle of the stakeholders;
- Ensuring good sensitivity;
- The design of a digital and scalable database;
- Simplify the data collection process;
- To know in detail the spatio-temporal characteristics of each region;
- Ensure good management (reliable, fast, and efficient);
- Allows the update and updating of data in real time;
- Allows the visualization of data;
- know the variation and spatio-temporal distribution of each disease in real time;
- bring the administration closer to the breeders and farmer;

- The GIS will also improve networking and communication between institutions responsible for livestock disease management (FAO, 2015; Gitonga, 2015; Kuldeep et al., 2013).

As it's already said this platform brings together different partners, so we have devised this application into different area (Veterinary area- Administration area- Agricultural area) and each one play a principal role in the veterinary field.

- **Veterinary area:** As its name indicates it is a space distinguished to all the veterinarians (state or private) that they can participate by filling in the boxes containing all the necessary information that are georeferenced and send to the stakeholders (fig.8).

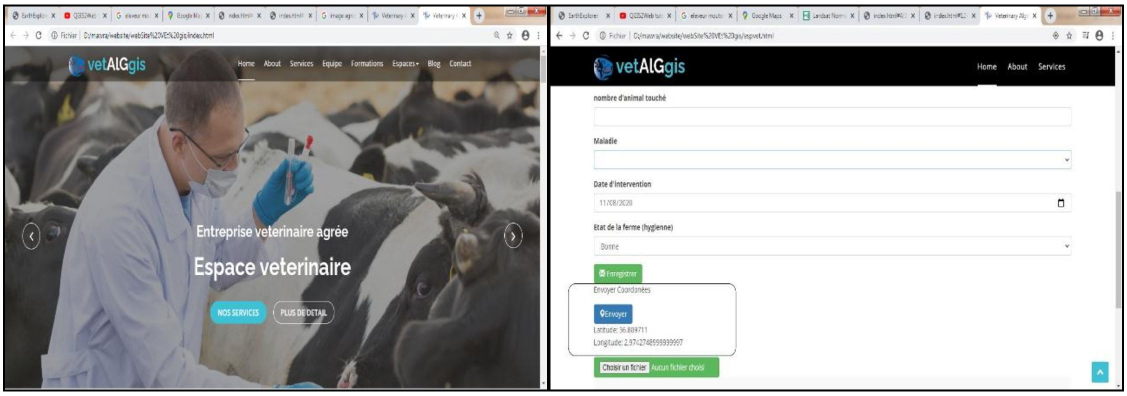

Figure 8. Veterinary area in VETALGIS Web application

- **Administration area:** A space dedicated to the collection of administrative data, facilitating the preservation and exchange of information with different partners, Knowing the needs and gaps that may exist in the stakeholder cycle. Which makes OF this space a reliable decision-making tool (fig.9)

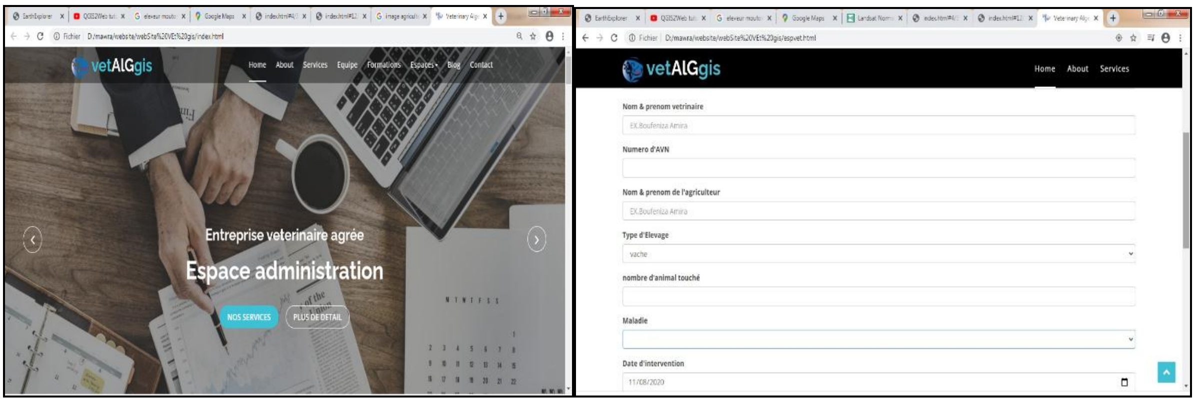

Figure 9. Administration area in VETALGIS Web application

- **Agricultural area:** A space dedicated to farmers and stockbreeders to enable them to express their concerns and to disclose to the relevant authorities the diseases and problems they face (fig.10).

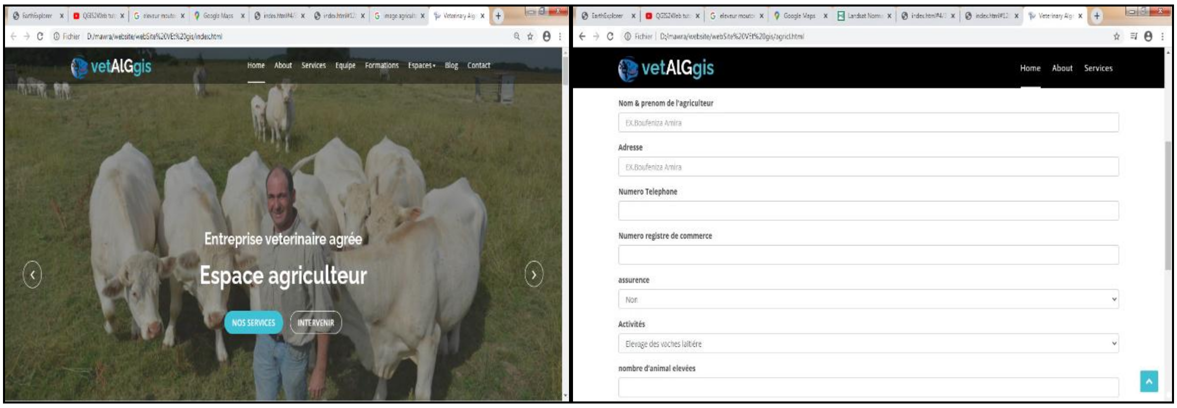

Figure 10. Agricultural area in VETALGIS Web application

IV.6 Methodology

This work focused on distribution analyses, which were performed using freely available Qgis 3.10.5 (https://www.qgis.org/en/site/).

To design a GIS, a methodology has been adapted based on the classical steps of GIS implementation, inventory and analysis of the existing situation, data acquisition, processing, production of value-added products, in this case the maps of livestock distribution and production, animal diseases and (FMD; PPR) according to the following flow chart: (Fig. 11).

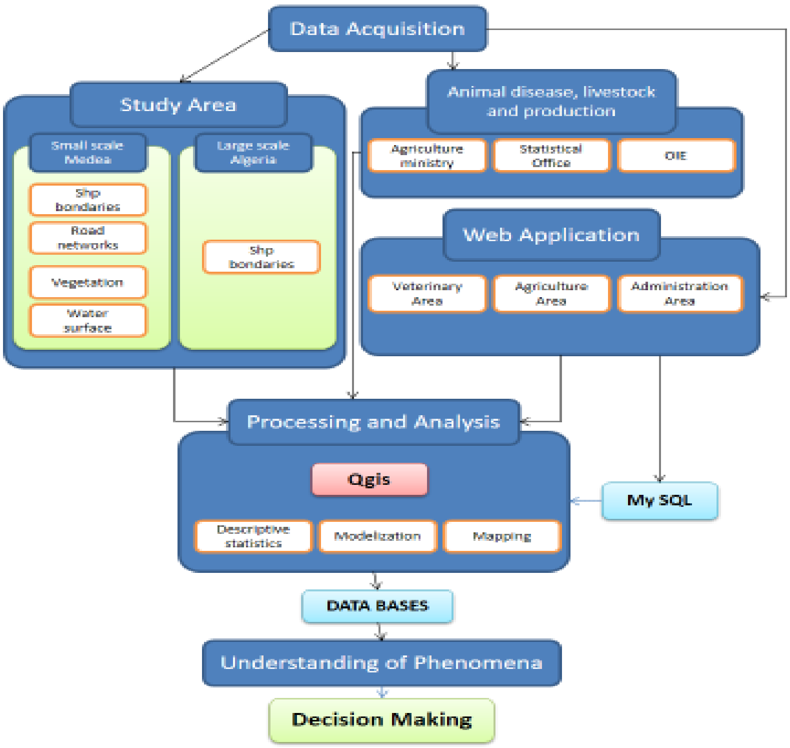

Figure 11. Work structure and methodology

IV.6.1 Data Acquisition

In Algeria livestock disease surveillance information is largely lacking, due to under reporting of disease incidence. (Catley et al., 2012; FAO, 2011; Prattley, 2009) and where the information is available it is available in different formats (papers, reports, Excel spreadsheet, Geographic coordinates...) and is distributed among different governmental and private institutions that do not have a sharing mechanism (FAO, 2011; Kuldeep et al., 2013).

Based on the definition of (Office Québécois de la langue française, 2004),spatial data acquisition can be defined as follows: "measuring spatial data, representing phenomena to be studied and intended for computer processing".

IV.6.2 Data Sources

IV.6.2.1 Administrative data

Administrative data are derived from the record-keeping activities of various organizations and/or the public sector. In our case data were collected from the Ministry of Agriculture and Rural Development of the People's Republic of Algeria (http://madrp.gov.dz/). These records include information such as animal population, disease outbreaks and are linked to geographical data by being captured at a particular address or region (hence the usefulness of relational databases). In this study the detailed information contained in the reports was structured in data bases and divided it into two scales (large and small scale).

- **Large scale**

The total number of animals in each province, including cattle, sheep and goats was collected from the Statistical Office of the ministry of agriculture of Algeria, from 2005 to 2017.

In order to investigate the distribution characteristics of FMD and PPR in Algeria, data of FMD and PPR cases from different years (2014-2015-2016-2018 for FMD and 2011- 2012-2013-2016-2018 for PPR) were collected from the Veterinary Services Direction of the ministry of agriculture of Algeria.

- **Small scale**

- Number of affected animals in the daïra of ksar el boukhari in 2019 were collected from (agriculture direction of media province " kasar el bukhari subdivision ").

IV.6.2.2 Survey data

They are data, which are collected for a specific purpose, often in a single procedure. Updating the data requires significant effort and can only be done occasionally. One of the main difficulties with survey data is that information quickly becomes obsolete, especially in countries with rapidly growing development and populations (Vinodhkumar et al., 2016).

In our case they are represented by geographical coordinates (x,y) derived from the addresses obtained from the direction agriculture direction of media province " kasar el bukhari subdivision.

IV.6.2.3 Internet data

Data of FMD and PPR cases reported in the last few years were collected from the World Organization for Animal Health (OIE) (http://www.oie.int/).

IV.6.3 data structuring and integration

A) Structuring

This step is essential for the establishment of a database, it refers to the assembly of data. The objective here is to manipulate the necessary data.

In short, the databases will be integrated into the GIS, they correspond to the data including the information on the study areas.

B) Integration

The data entry component converts data from its existing form into a form that can be used by the GIS. Data for use in a GIS may be available in a variety of formats

- **The input of geographical data:** The concepts of georeferencing are necessary to understand how each collected information is referred at area or point of the earth into a two-dimensional plane otherwise; geographical data represents a relatively complex entity of the real world.

- **Entering descriptive data:** it can be done in two ways: interactively, by selecting a spatial entity and directly assigning descriptive attributes; or through data files created elsewhere (in Excel).

- **The entry of map holdings:** Data integration requires a good resolution background map in order to better locate the sampling stations and the different data of the study areas, and we opted for DZ Admin 0;1;2 ......

IV.6.4 data combination

Both spatial and geographical data are combined with epidemiological data allowing the analysis of variables This data combination is essential for health policy planning, decision-making and ongoing surveillance efforts (Bhatt & Joshi, 2012; TS & AW, 2017).

In this case, the vector layer "DZ Admin " download from national institute for mapping and remote sensing (INCT) (http:// www.inct.mdn.dz/webinctsim/ telechargement.php). The second vector layer is in the form of a point, contains the information collected on the ground and/or acquired from the Minister of the Ministry of Agriculture and Rural Development (MADR) concerning the fields of information shown; In this case, they are:

- Number of the municipalities;

- Number of the parcel;
- Disease type;
- Area;
- Type of breeding;
- Number of affected animal.

IV.6.5 Data analysis and processing

There are several categories of processing and analysis, that can be carried out by a GIS in various ways; either according to:

- The type of object (point, line, surface, volume)
- The structure of the data (vector, raster)
- The modified characteristic (geometric, thematic, temporal or topological)
- The level of measurement of the variable (univariate, multivariate)
- The scale of measurement (quantitative or qualitative)
- To their purpose (descriptive, exploratory and confirmatory)

To explore how cases are distributed in each province and analyze the distribution of FMD and PPR cases where all provinces were considered as a whole, Global spatial autocorrelation was applied Spatial autocorrelation analysis was used to investigate the presence of clustering and its type. FMD incidence rate was taken as attribute value for each province (Jeefoo et al., 2010).

IV.7 Converting the Data to Web map information's

The first step in publishing GIS services is to create the GIS resources that will be the basic parameter of any web service. Once the database is created, a GIS service allows access to the database via a local area network (LAN) or the Internet using the QGIS server. Authorized users can also use Geo-data services to periodically synchronize changes to databases on the Internet. When the publication process is complete, a map service and a geo-data service with the same name are created and can be managed independently. Consequently, the present work was formulated and generated on the basis of a tabular data model (Das et al., 2019).

IV.7.1 Qgis2Web

It is an important operation of GIS, that can be installed giving us the ability to share data over the net, allowing rapid long-distance exchange and optimizing economic resources (Andreopoulou, 2011).

Qgis2Web allows creating an employment web-map, in which the user can easily find information. It can be attached, for example, to the web site of the disease animal with an informative aim. Even though the complexity of the process increases with the number of the layers shown, the process of creation of the map remains fast and doesn't require a complicated training of the operator and The result is an html file, which can be opened with a web browser (Gabriele Garnero & Ingrid Vigna, 2018).

The Qgis2Web plugin provides an easy way to distribute and view Qgis work as a web map using Open Layers or LeafLet extensions. With this plugin, you can export your Qgis project as an html page by creating a directory containing the index.html page and subdirectories with everything you need to view the map, as well as the data used. The Qgis2WEB plugin exports the vector layers in GeoJSON format, creates the basis of the web map using the current version of Leaflet or OpenLayers (optional). In addition, the plugin adds raster data as image overlays with an opacity slider.

Chapter V
Results and discussion

V. Results and discussion

V.1 Results

the results are divided in our work to two mean parts:

V.1.1 Mapping results

- **Large scale**

A/ Production

A.1/ Milk production

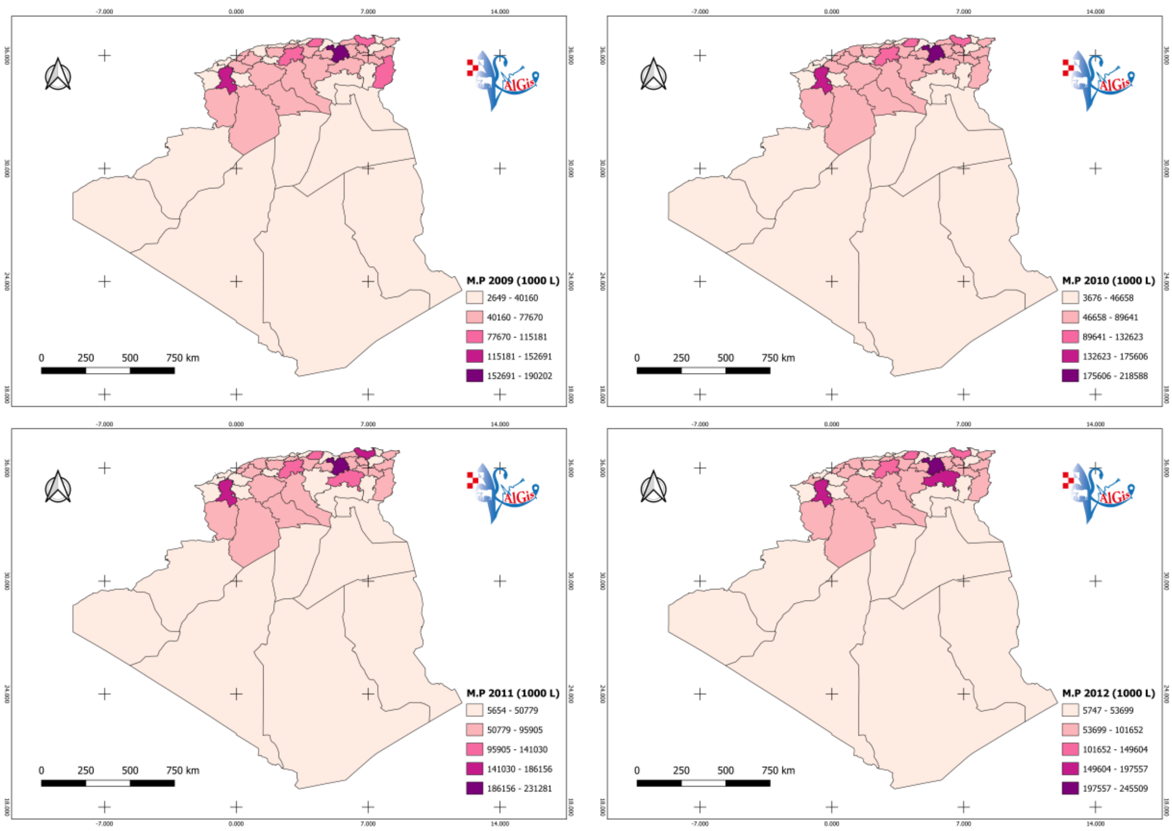

Figure 12. Milk production from 2009 to 2012.

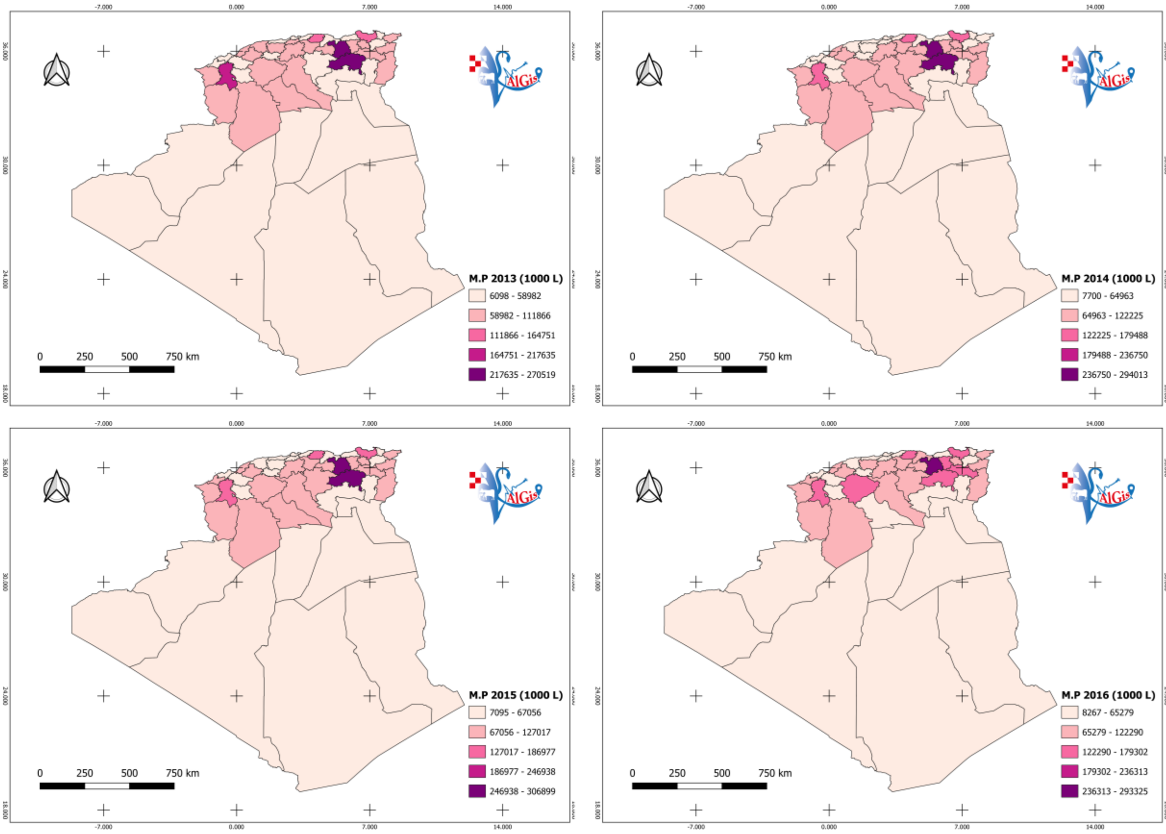

Figure 13. Milk production from 2013 to 2016

We note that the rate of milk production is concentrated in the Highlands region where the wilaya of Setif occupied the first place in milk production during the eight years (from 2009 to 2016), followed by Batna and Sidi Bel Abbas. And some state of the Coastal strip like Skikda and Tizi Ouzou (fig.12 and 13).

A.2/ Cow milk production

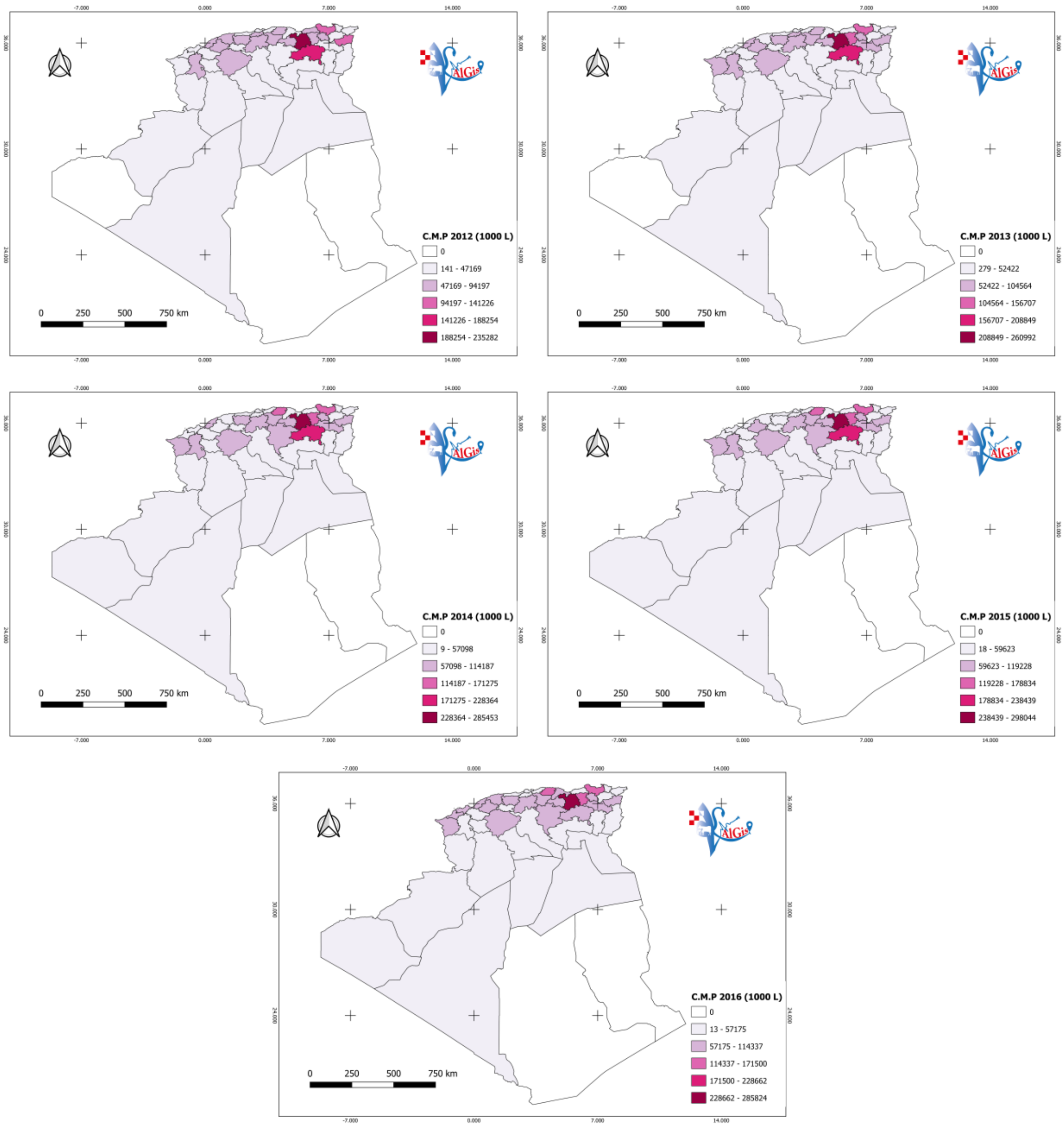

Figure 14. Cow milk production from 2012 to 2016.

Cow's milk production is concentrated in the majority of the coastal band states and in the Highlands region, with the highest production in Setif and Batna (fig.14).

A.3/ Red meat production

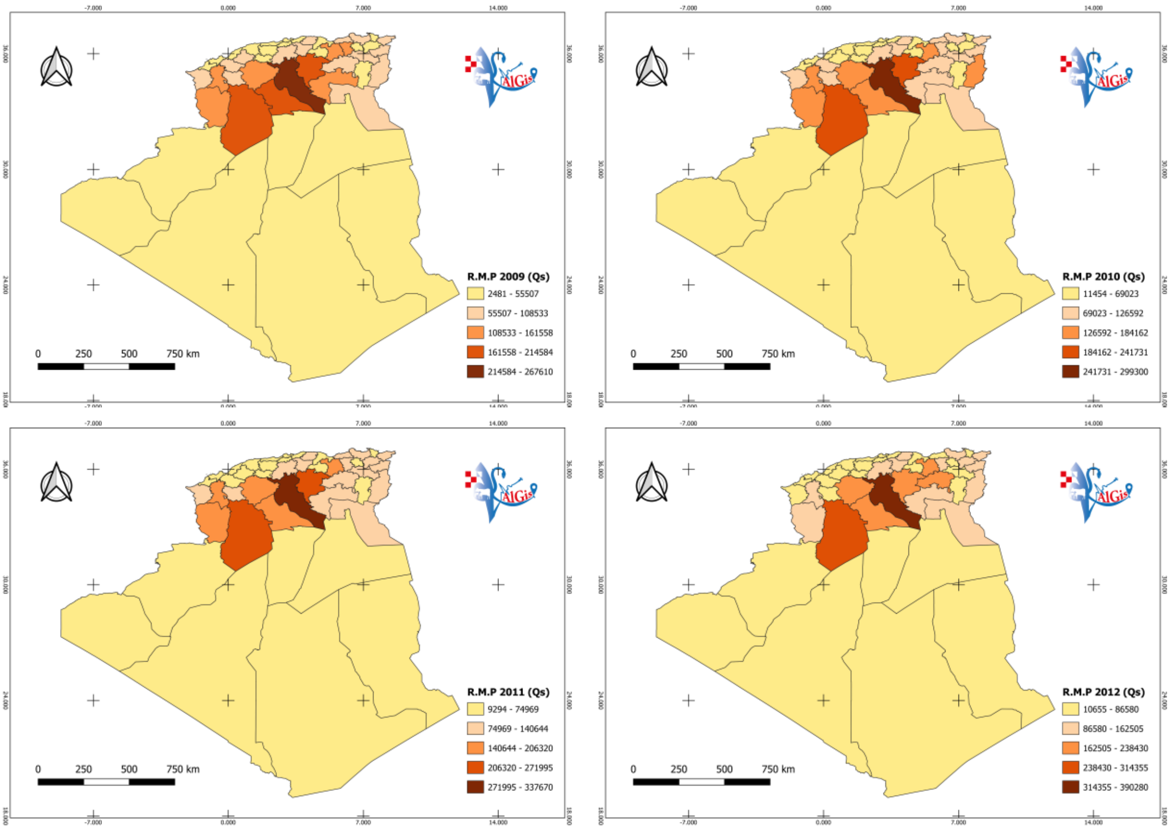

Figure 15. Red meat production from 2009 to 2012.

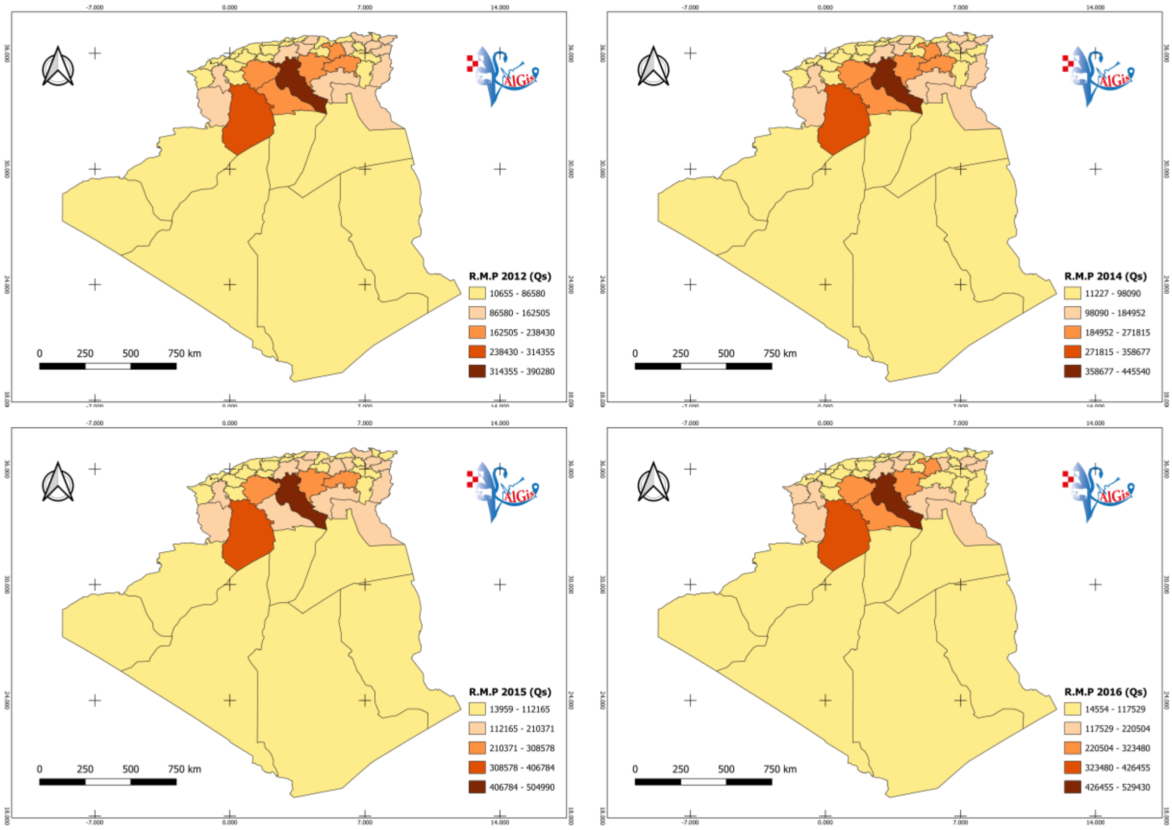

Figure 16. Red meat production from 2013 to 2016.

The maps show that during all those eight years Djelfa occupied the first place in the production of red meat, followed by El Bayadh, Laghouat, M'Sila, Setif and then some other states from the high plateaux and coastal band (fig. 15 and 16).

A.4/ Bovine meat production

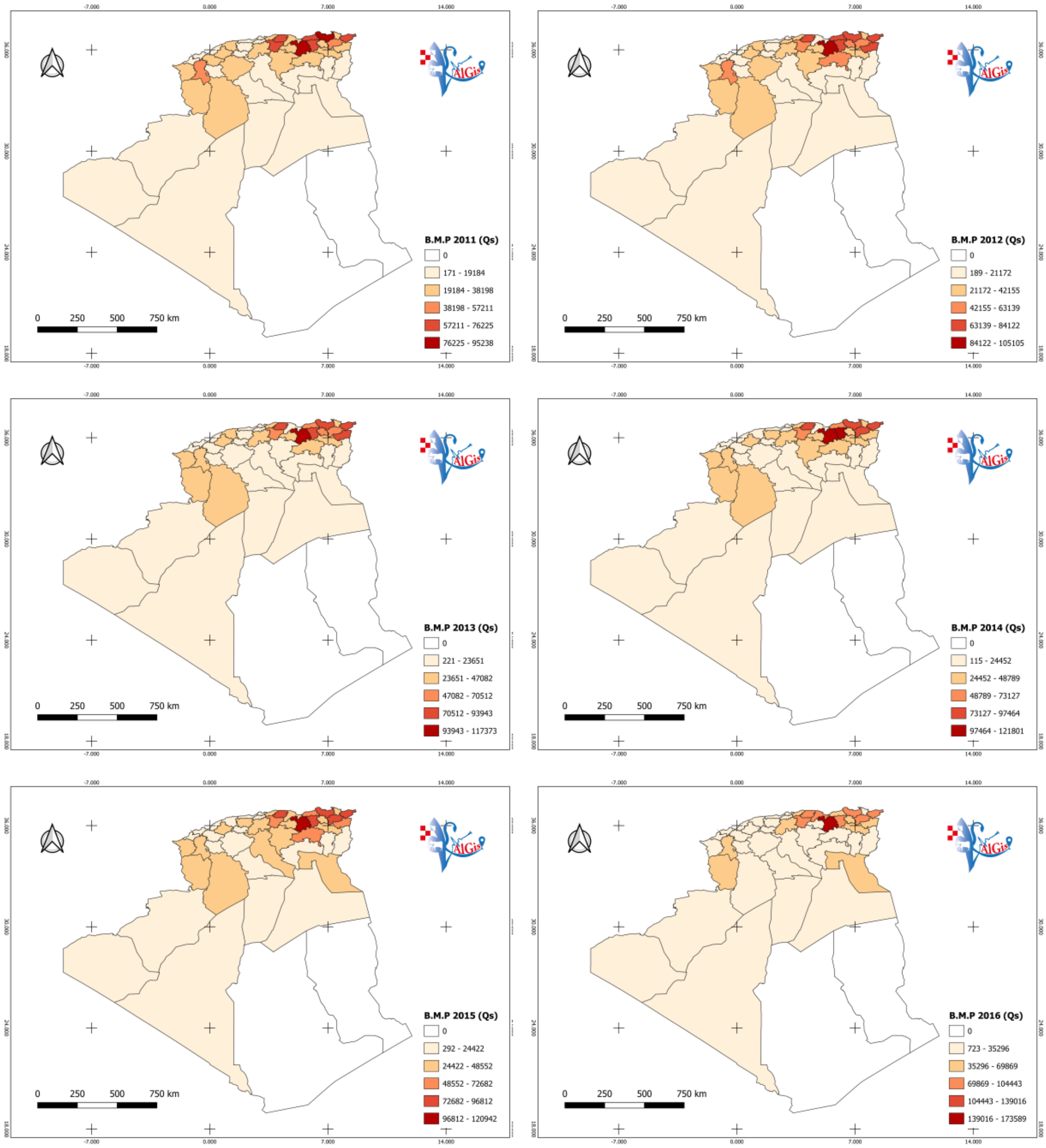

Figure 17. Bovine meat production from 2011 to 2016.

Those maps show a high bovine meat production on the eastern coast and the eastern interior states such as Setif, Mila, Guelma, Souk Ahras; Taref, Skikda,...ect. There is also an almost non-existent production in the desert regions of the extreme south (fig.17).

A.5/ Ovine meat production

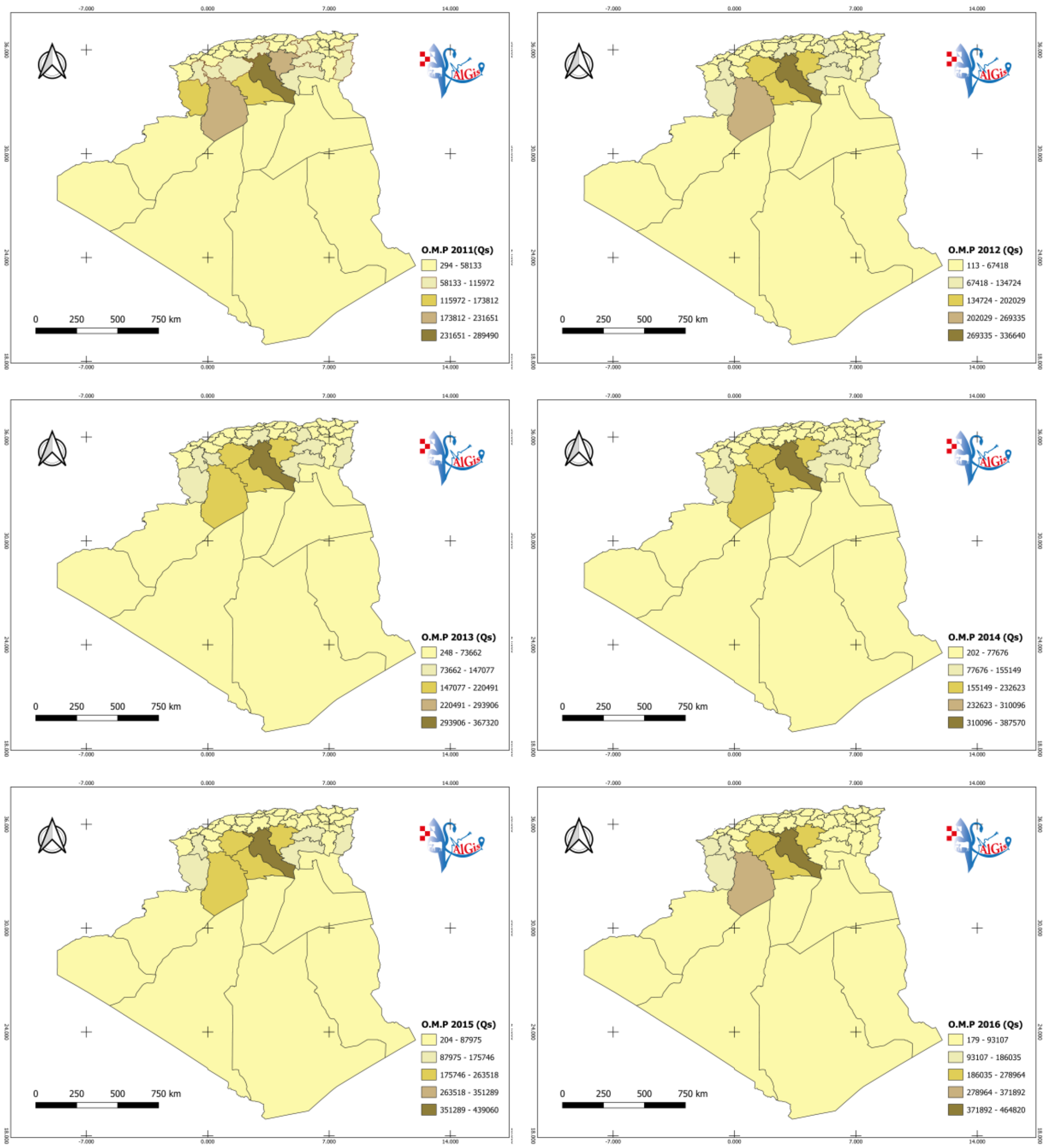

Figure 18. Ovine meat production from 2011 to 2016.

We can notice from those maps that ovine meat is highly produced in those states: Djelfa, El Bayadh, Msila, Laghouat and Tiaret ,in addition to considerable production in the rest of the country's states (fig.18).

B/ Livestock population

B.1/ Bovine livestock population

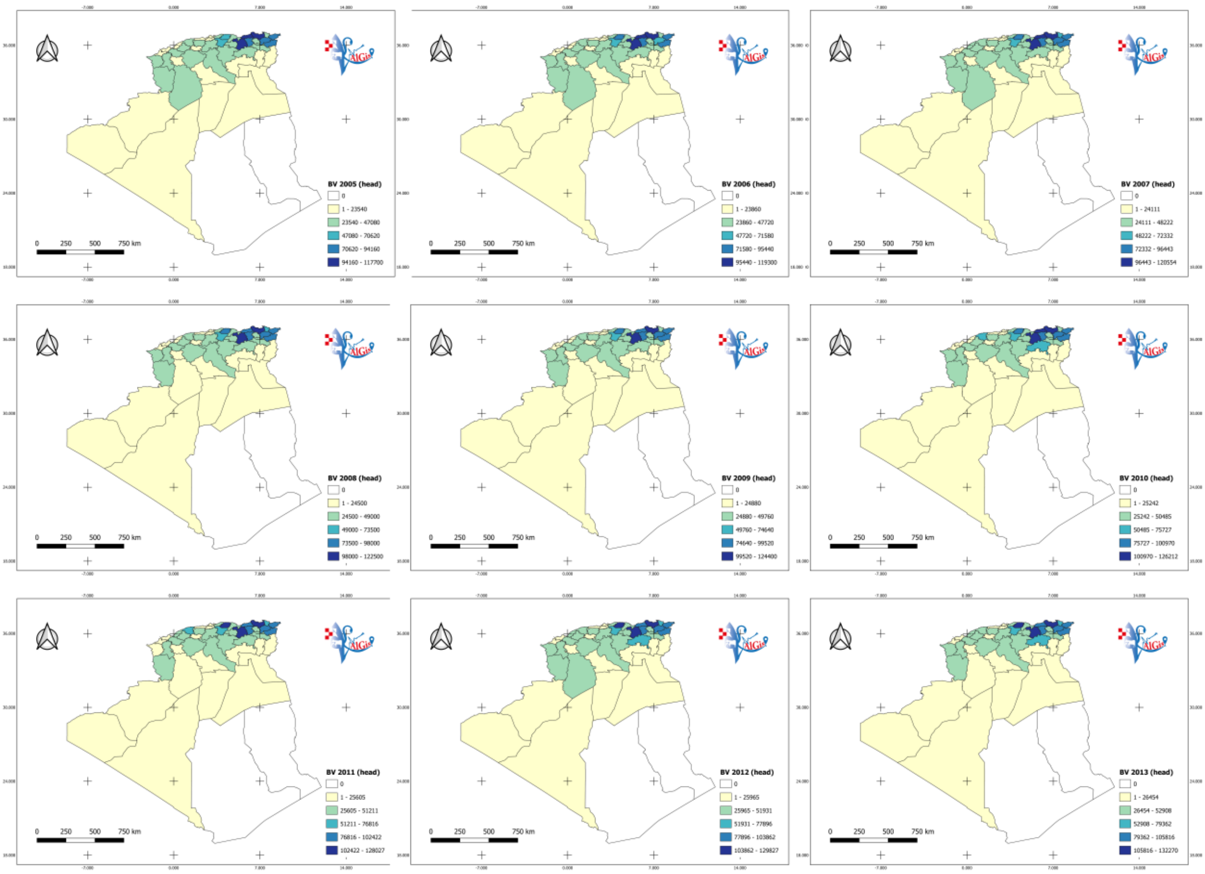

Figure 19. Bovine livestock population from 2005 to 2013.

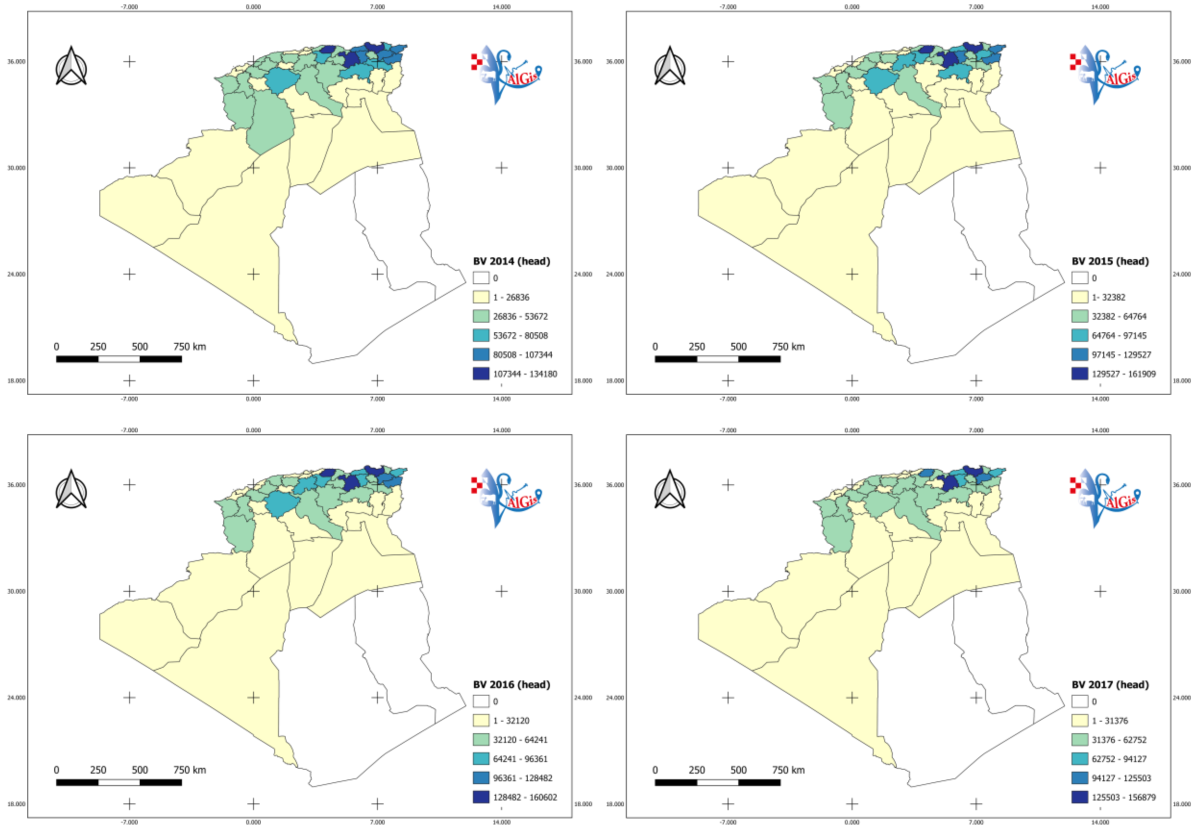

Figure 20. Bovine livestock population from 2014 to 2017.

Bovine livestock population in Algeria from 2014 to 2017 (fig.19 and 20), show a High density in the coastal and interior states, especially the eastern ones while in the Saharian regions, a low density is noted.

B.2/ Caprine livestock population

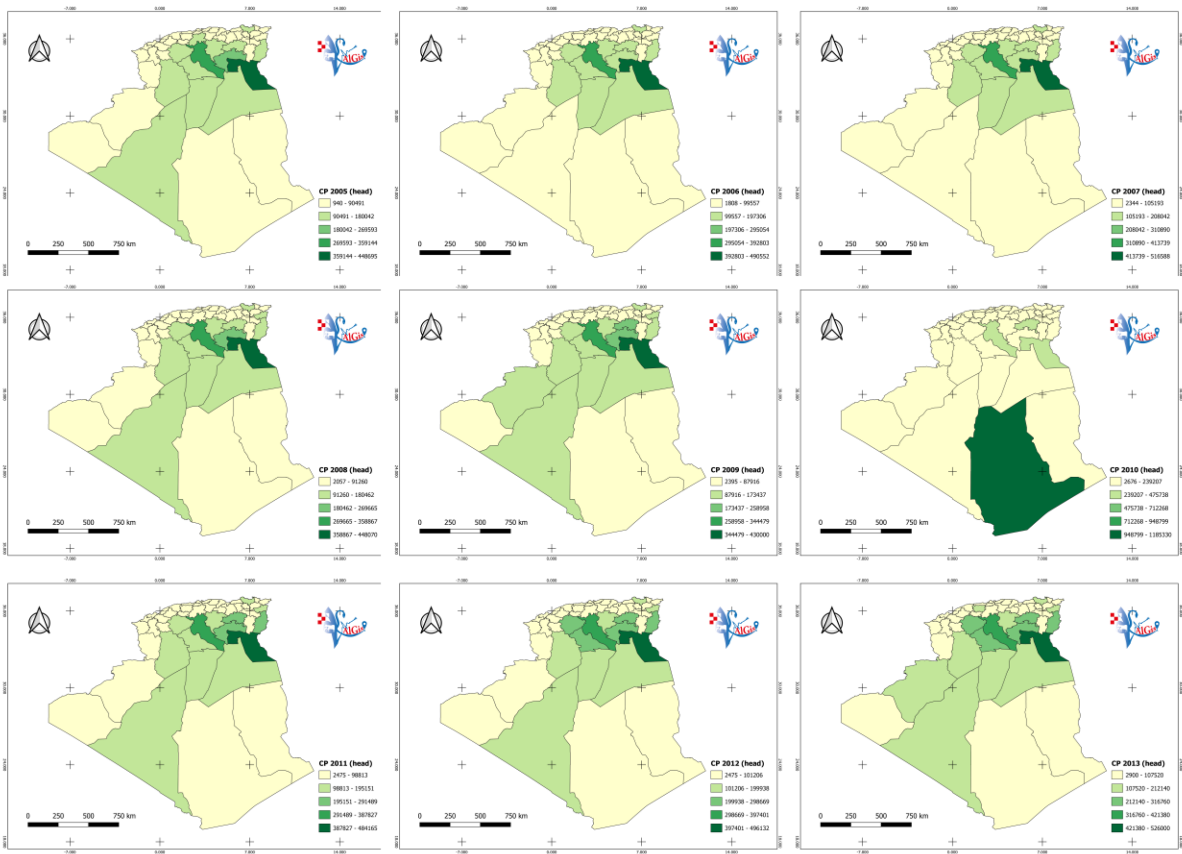

Figure 21. Caprine livestock population from 2005 to 2013.

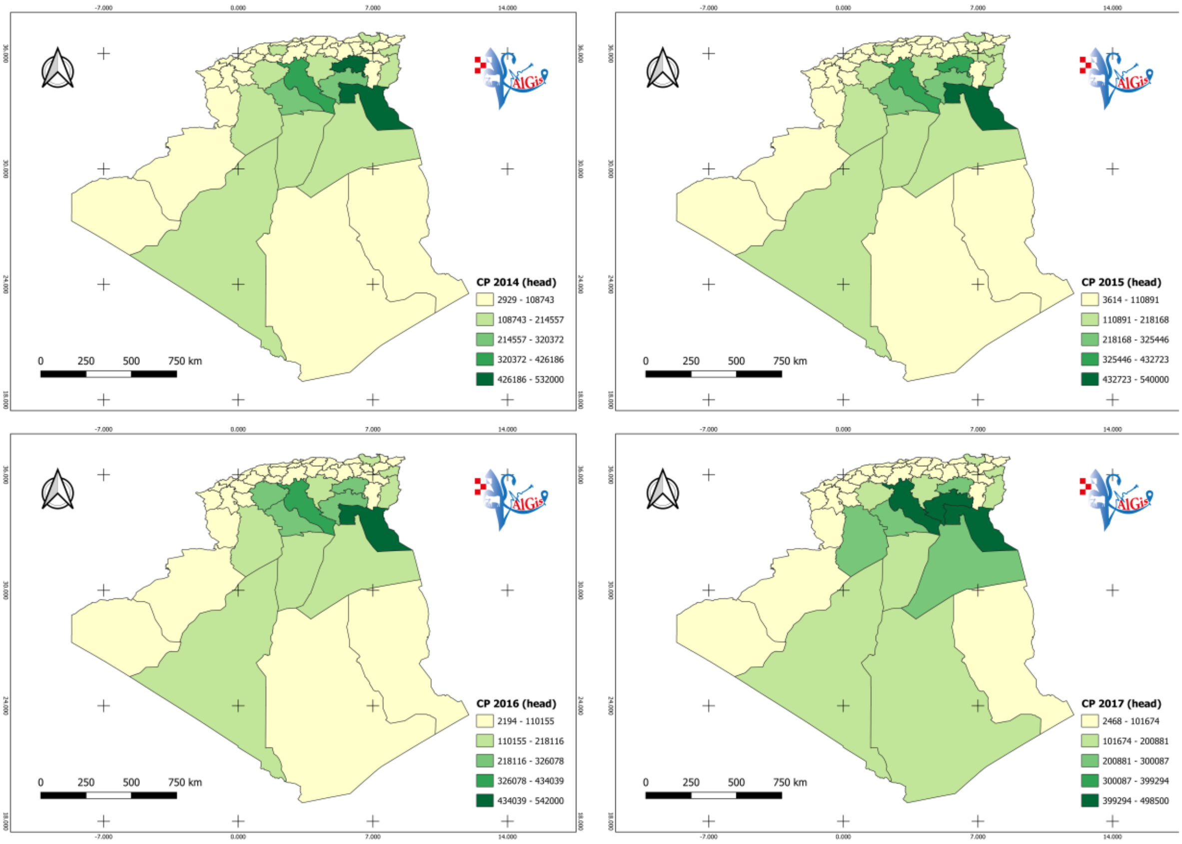

Figure 22. Caprine livestock population from 2014 to 2017.

For the caprine livestock we noticed a Random distribution over the years, principally in Highlands and Desert regions like Djelfa, Biskra ,El Oued, Ouargula, Guerdaia, Adrar....ect (fig. 21 and 22).

B.3/ Ovine livestock population

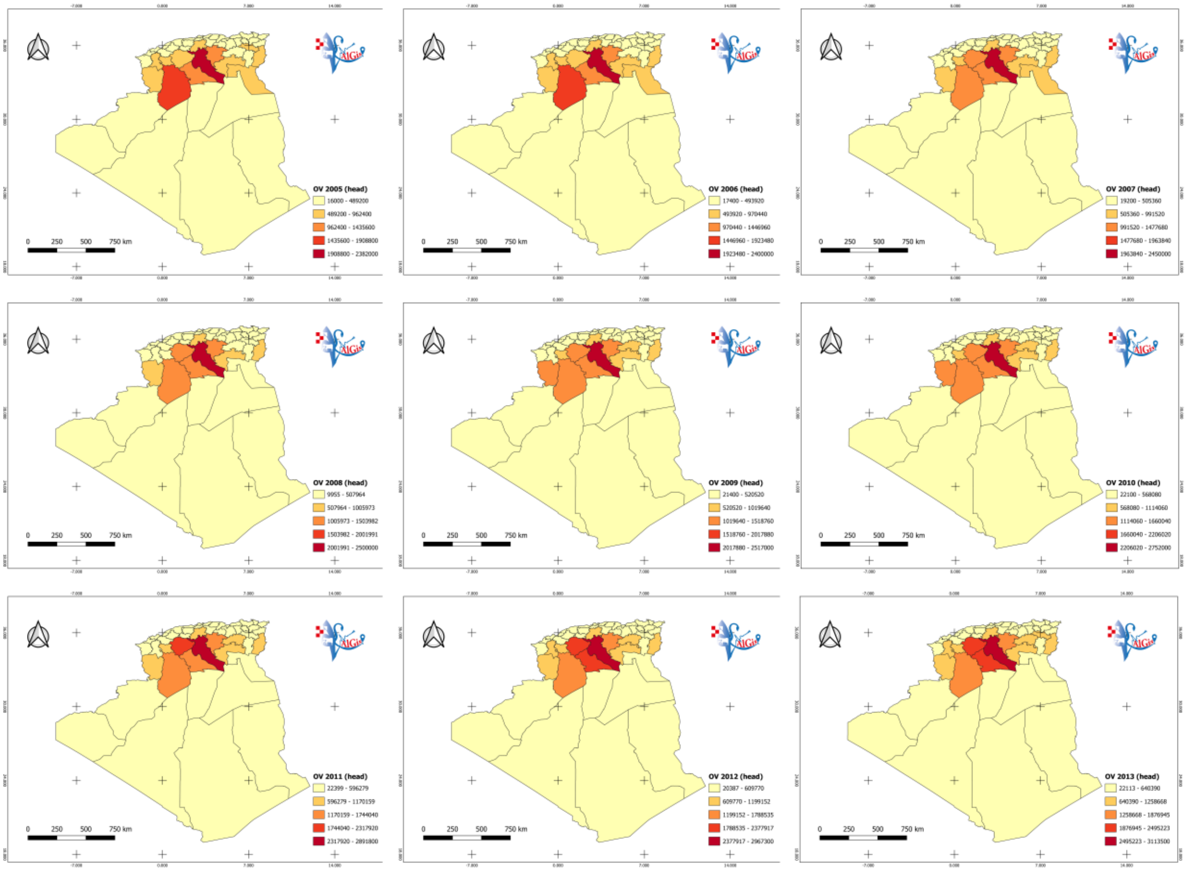

Figure 23. Ovine livestock population from 2008 to 2013.

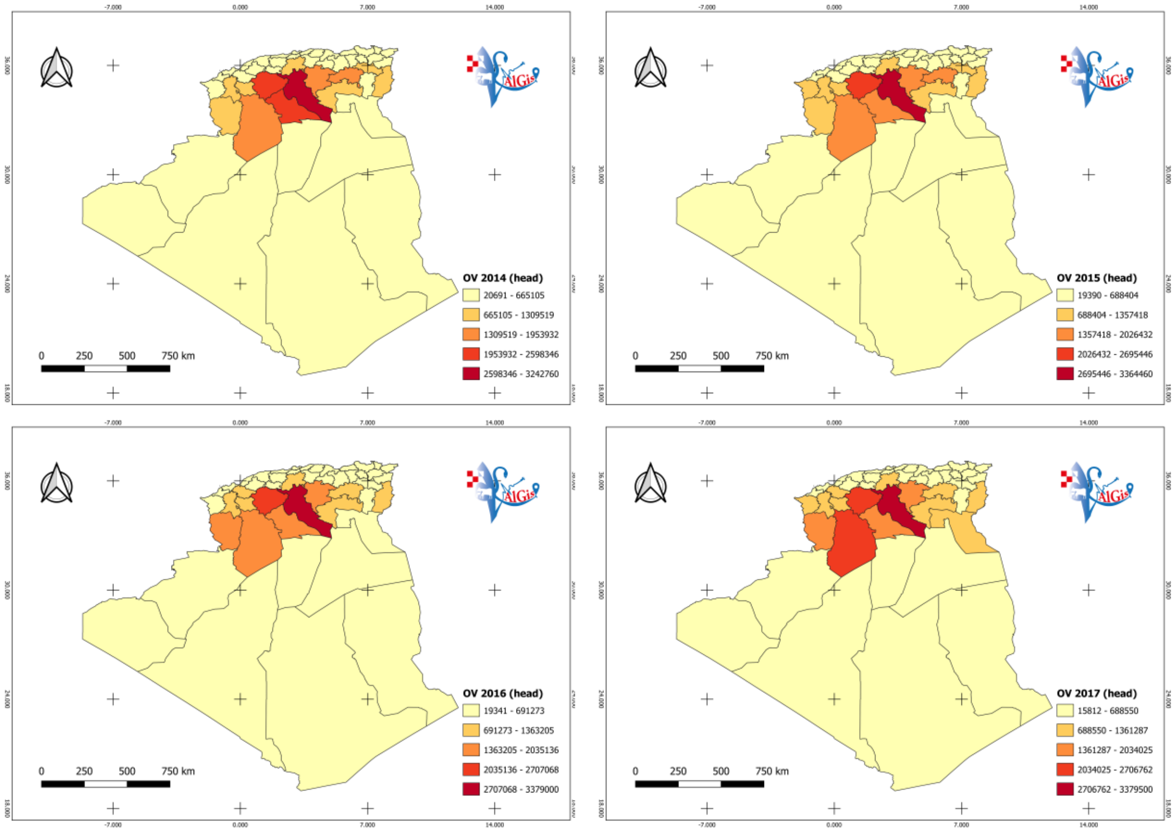

Figure 24. Ovine livestock population from 2014 to 2017.

The distribution of ovine livestock in Algeria is noticed in the interior states and northern Sahara with a hight density in Djelfa, Tiaret, El Bayadh, Laghouat, Msila (fig.23 and 24).

C/ PPR results

C.1/ Caprine PPR

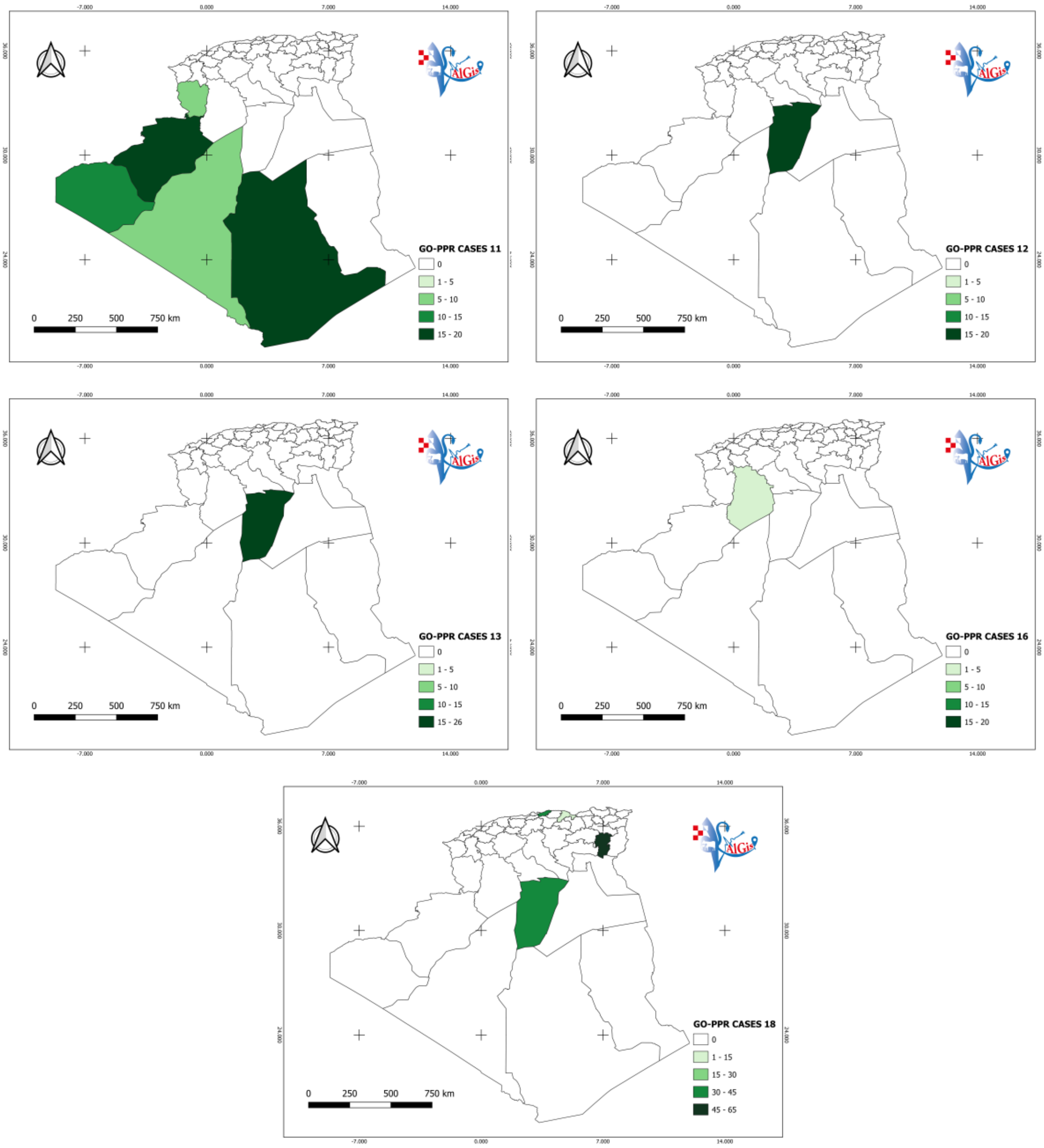

Figure 25. PPR in caprine in 2011, 2012, 2013, 2016, 2018 respectively.

The maps (fig. 24), show that Caprine PPR cases in Algeria were concentrated in saharian states (Tamanghaset, Bechar, Tindouf, Adrar ..) in 2011 while some cases have been reported in Ghardaia in 2012 and 2013 and in Beyedh in 2016. For 2018 we've record the highest level of cases in Khanchla, Ghardaia, Bejaia and Boumerdas.

C.2/ Ovine PPR

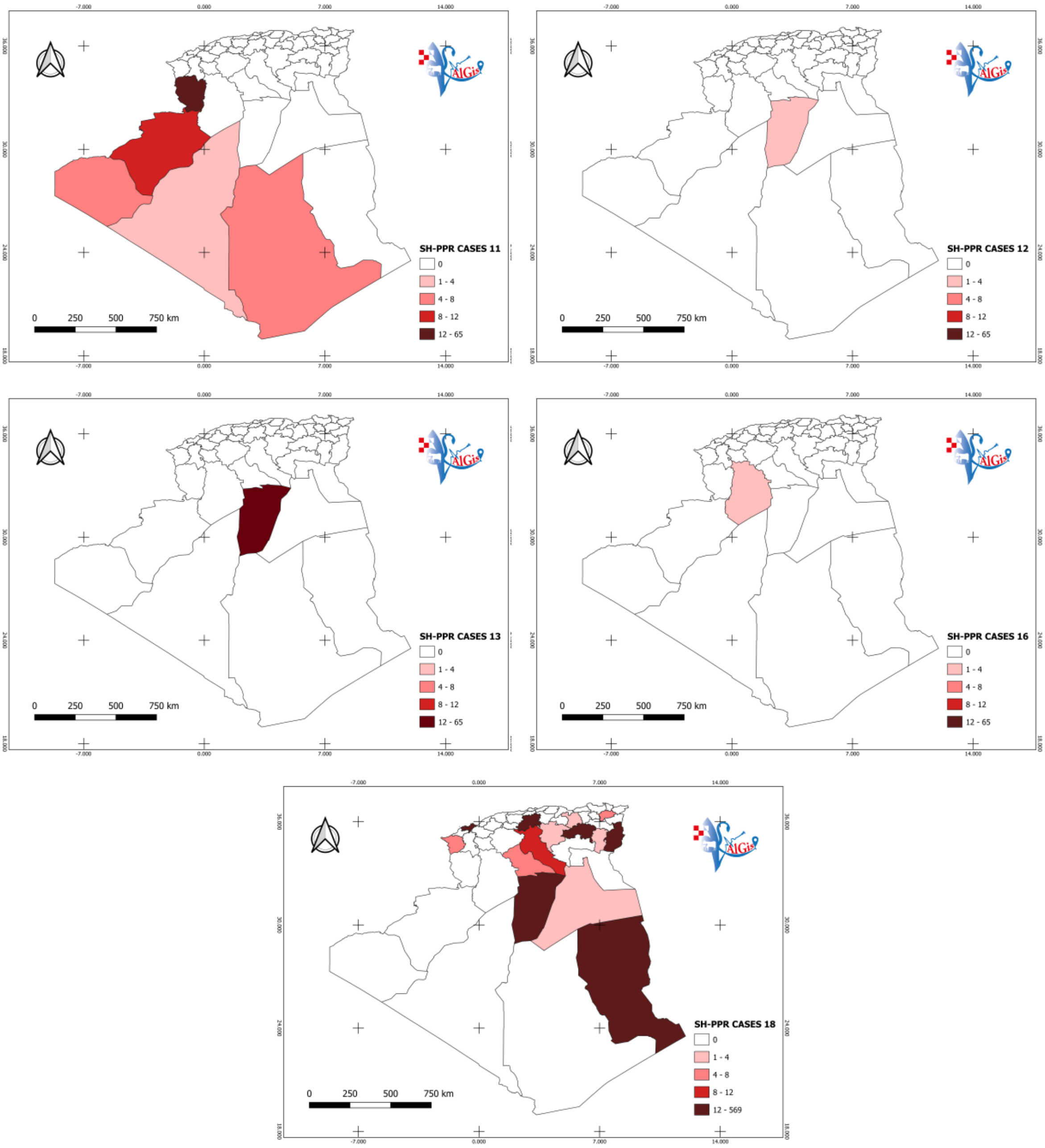

Figure 26. PPR in ovine in 2011, 2012, 2013, 2016, 2018 respectively.

Those maps (fig. 26), show a random distribution of cases over the years (2011, 2012, 2013, 2016, 2018 respectively). The highest number of cases was reported in 2018 in Illizi, Ghardaia, Tbessa, Khanchla, Medea and Oran.

D/ FMD results

D.1/ Bovine FMD

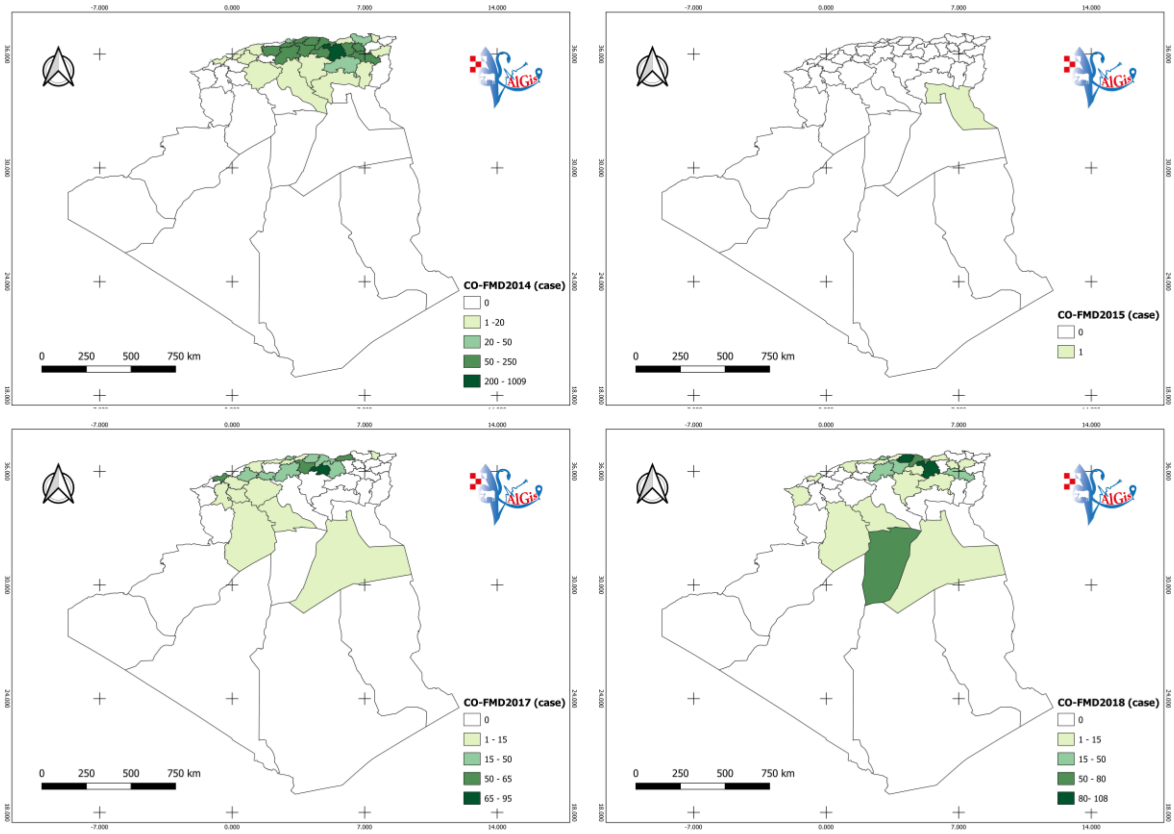

Figure 27. FMD in bovine in 2014, 2015, 2017, 2018 respectively.

Bovine FMD cases were recorded in the northern and interior states in 2014 while we record just one case in El Oued in 2015 and for 2017 and 2018 we recorded cases from different states of the coast, the interior and the north of Sahara. The highest number of cases was reported from Setif (fig. 27).

D.2/ Ovine FMD

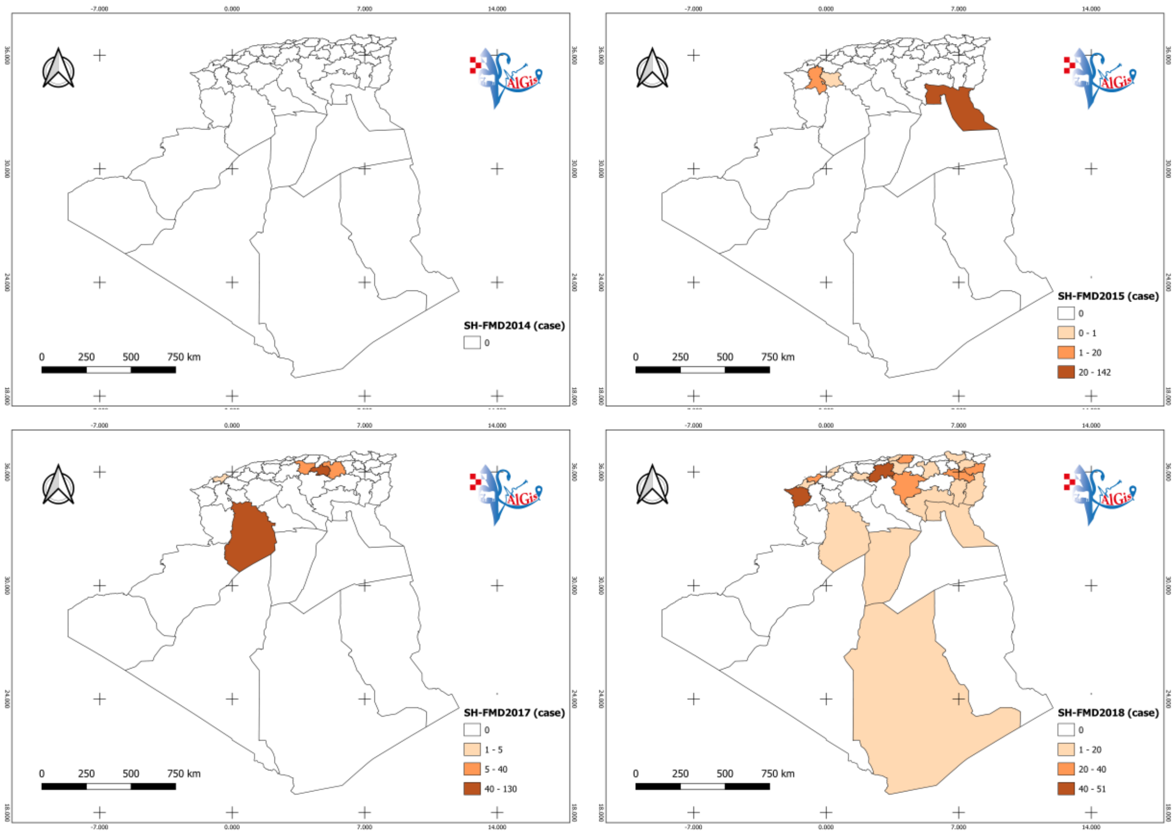

Figure 28. FMD in ovine from 2014, 2015, 2017, 2018 respectively.

No case ovine FMD was registered in 2014 while we record the highest number of case in El Oued in 2015 and in 2017 and 2018 we recorded cases from different states of the interior and Sahara (fig. 28).

D.3/ Caprine FMD

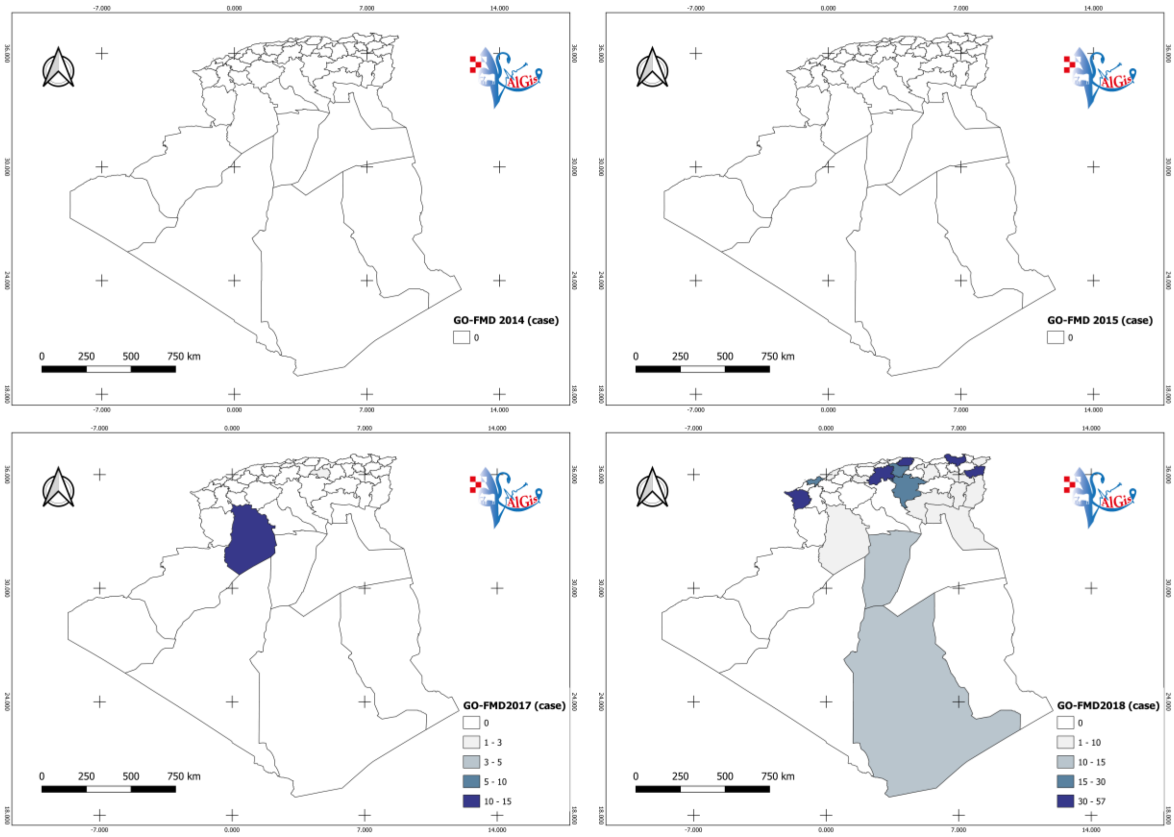

Figure 29. FMD in caprine from 2014, 2015, 2017and 2018 respectively.

No case caprine FMD was registered in both 2014 and 2015, while in 2017 we registred some cases in Beyedh and we recored the highest number of case in 2018 in Souk Ahras, Skikda, Medea, Tizi Ouzou and Tlemcen (fig. 29).

➢ **Small scale**

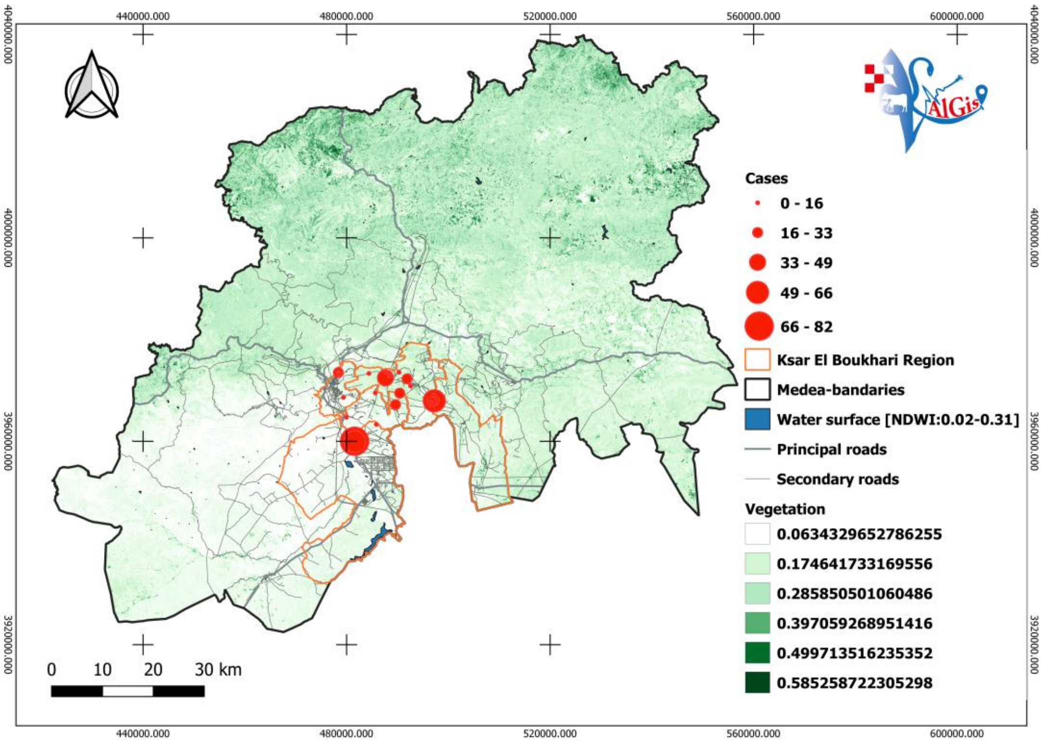

Figure 30. Mdea's map showing FMD outbreaks which were declared in January and february 2019.

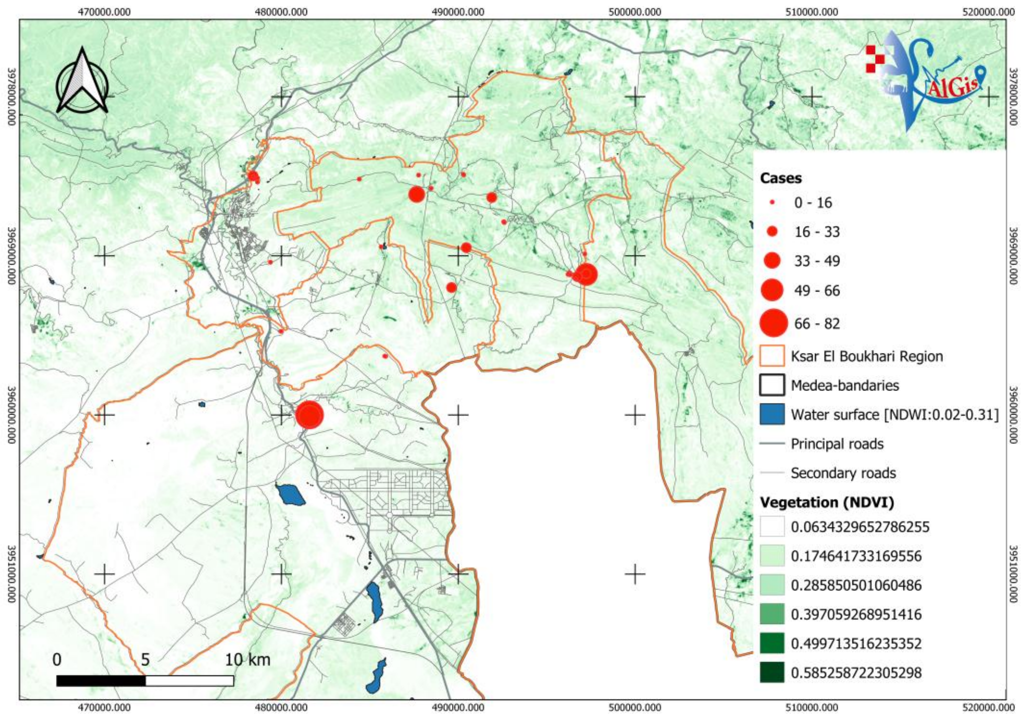

Figure 31. FMD outbreaks in Kser El Boukhari region declared in January and February 2019.

We remark from those figures (29 and 30), that FMD outbreaks were declared in Saneg, mfatha, and kser Kser El Boukhari .

E/ Web map results

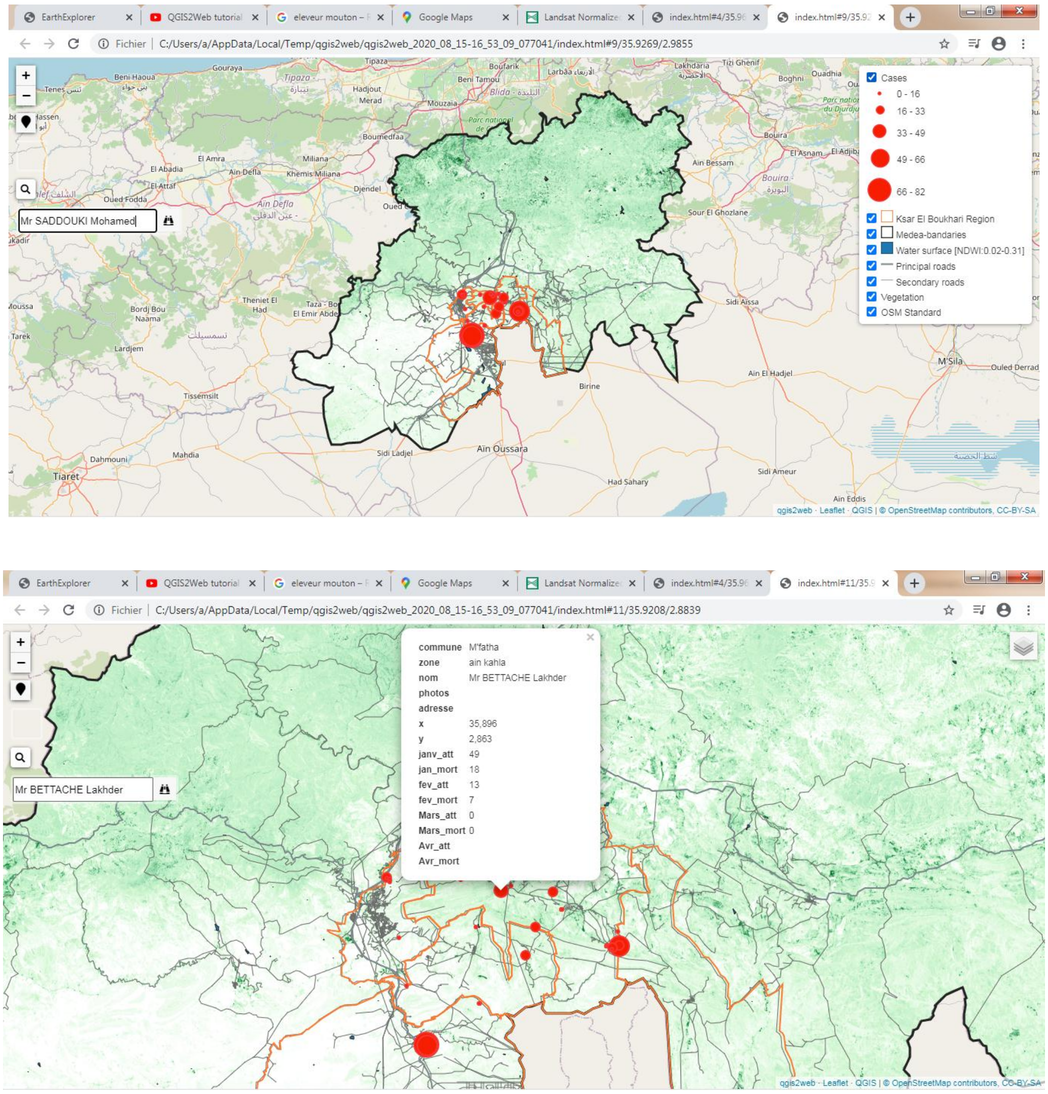

Figure 32. Medea's web map exported by the plugin QSGis2Web.

This figure (31), shows the map that we've completed and exported in the web and how we can have all outbreaks informations with one clic.

V.1.2 Statistical results

- **Large scale**

A/ Production results

A.1/ Milk production

Table 1. Statistical results of milk production from 2009 to 2016.

M.P (1000L)	2009	2010	2011	2012	2013	2014	2015	2016
Min	2649	3676	5654	5747	6098	7700	7095	8267
Max	190202	218588	231281	245509	270519	294013	306899	293325
Average	49879,1667	54852,2917	60978,2708	64337,2917	70168,0625	73933,8333	78203,4583	74937,8542

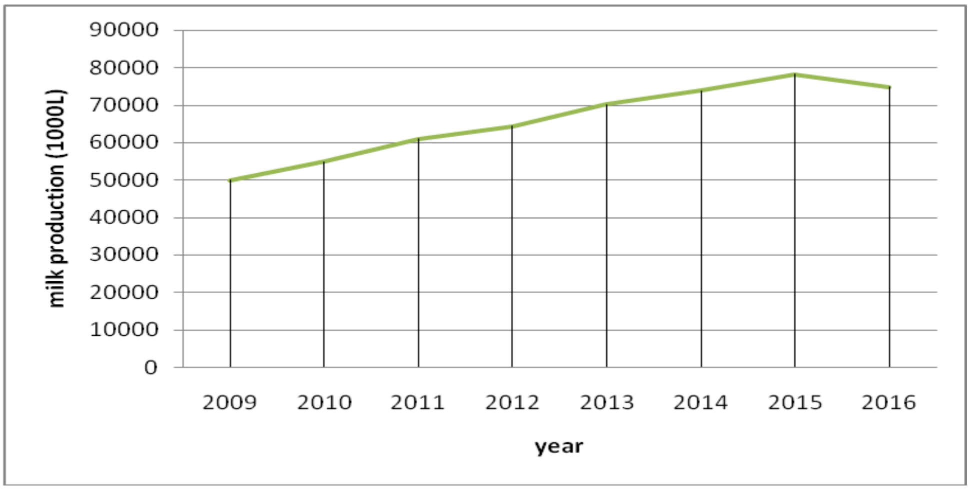

Figure 33. Average of milk production from 2009 to 2016.

The rate of milk production in Algeria over these years formed an upward trend until reaching its peak in 2015 with an average of 78203.4583 (1000L) then decrease a little bit in 2016 (tab. 1 and fig. 33).

A.2/ Cow milk production

Table 2. Statistical results of cow milk production from 2012 to 2016.

C.M.P (1000L)	2012	2013	2014	2015	2016
Min	0	0	0	0	0
Max	235282	260992	285453	298044	285824
Average	47709,4583	51966,7083	54588,9792	59240,75	55155,3542

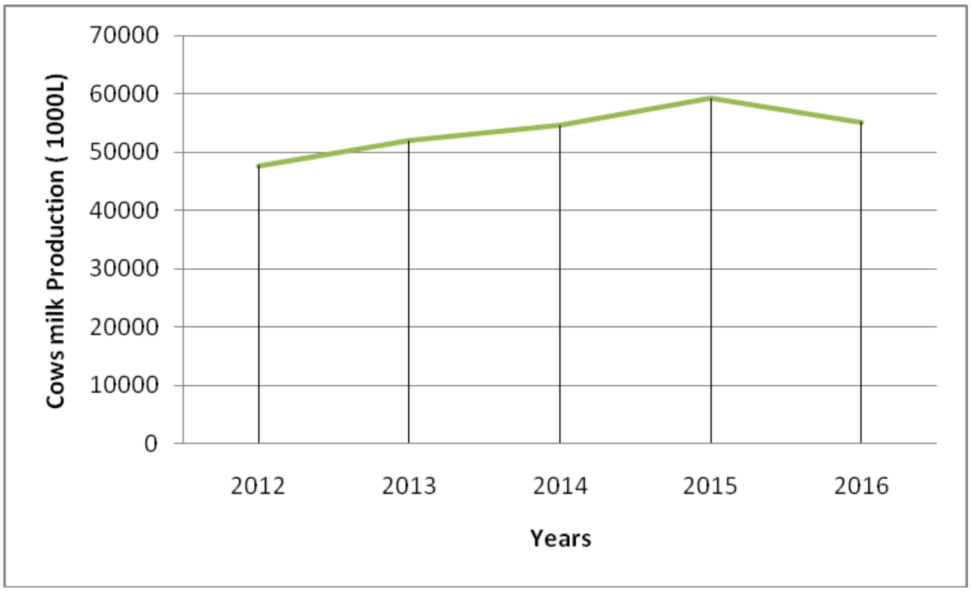

Figure 34. Average of cow milk production from 2012 to 2016.

The rate of cow milk production in Algeria over 5 years (2012 to 2016), shows an increase trend until reaching its peak in 2015 with an average of 59240,75 (1000L) and then decrease a little bit in 2016 (tab. 2 and fig. 34).

A.3/ Red meat production

Table 3. Statistical results of red meat production from 2009 to 2016.

R.M.P (Qs)	2009	2010	2011	2012	2013	2014	2015	2016
Min	2481	11454	9294	10655	11007	11227	13959	14554
Max	267610	299300	337670	390280	423430	445540	504990	529430
Average	72208,3542	80687,5208	87406,8125	91622,625	97333,2708	101310,521	109509,917	112032,25

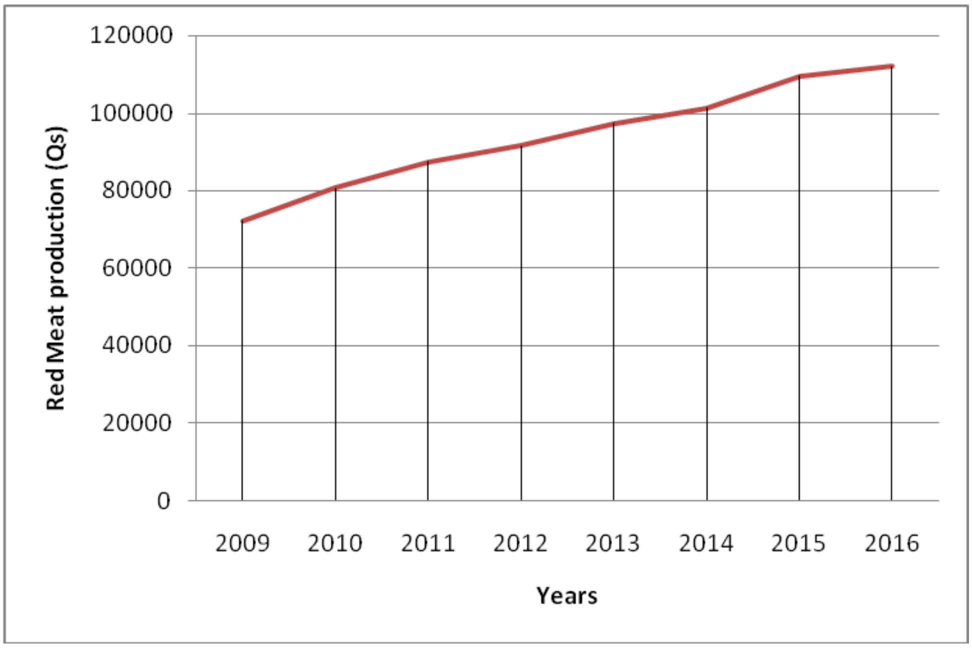

Figure 35. Average of red meat production from 2009 to 2016.

We notice a considerable height in red meat production in Algeria (Fig. 35), where the average reached 72208, 3542 Quintal (1 Qs=100 kg) in 2009 to achieve 112032,25 Quintal in 2016 (tab. 3).

A.4/ Bovine meat production

Table 4. Statistical results of bovine meat production from 2011 to 2016.

B.M.P (Qs)	2011	2012	2013	2014	2015	2016
MIN	0	0	0	0	0	0
MAX	95238	105105	117373	121801	120942	173589
Average	26122	28265,375	29150,125	30359,2917	32299,4375	34968,4375

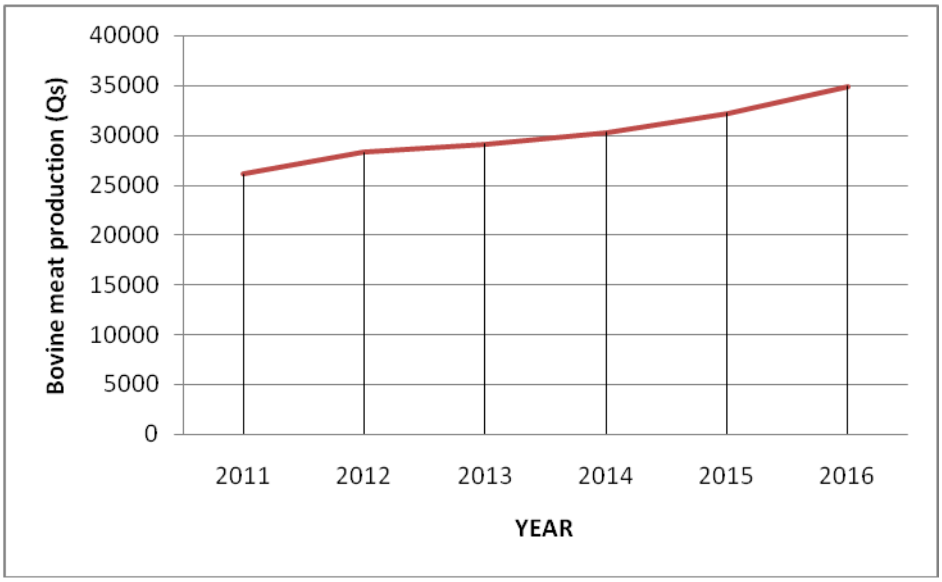

Figure 36. Average of bovine meat production from 2011 to 2016.

The average of cow milk production in Algeria over 6 years (2011 to 2016) shows a slow increase trend until reaching its peak in 2016 with an average of 34968,4375 Quintal (tab. 4 and fig. 36).

A.5/ Ovine meat production

Table 5. Statistical results of ovine meat production from 2011 to 2016.

O.M.P (Qs)	2011	2012	2013	2014	2015	2016
Min	294	113	248	202	204	179
Max	289490	336640	367320	387570	439060	464820
Average	52751,5833	54412,1458	58157,9167	60549,7292	66242,0833	67060,4167

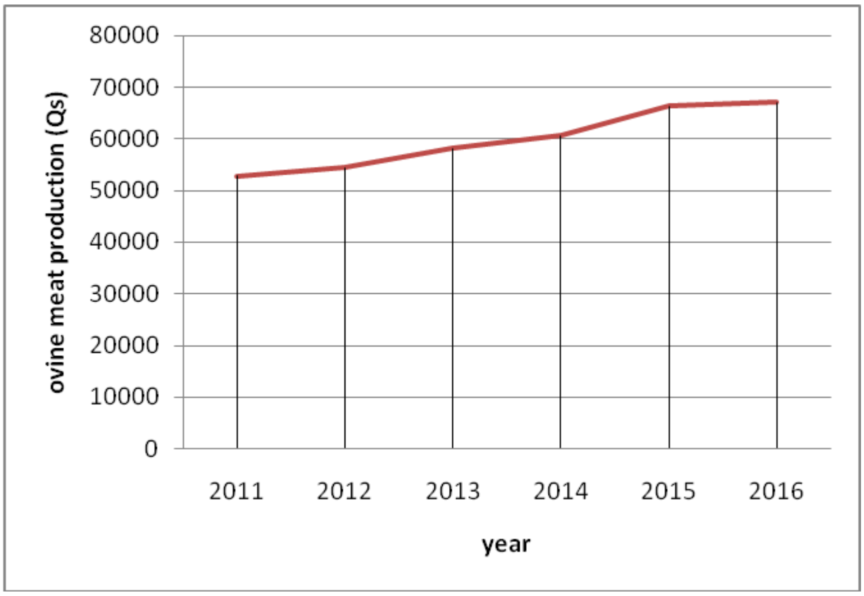

Figure 37. Average of ovine meat production from 2011 to 2016.

The average of cow milk production in Algeria over 6 years (2011 to 2016) shows a slow increase trend until reaching its peak in 2016 with an average of 67060,4167 Quintal (tab. 5 and fig. 37).

B/ Livestock population

B.1/ Ovine livestock population

Table 6. Statistical results of ovine livestock population from 2005 to 2011.

Ovine	2005	2006	2007	2008	2009	2010	2011
Min	16000	17400	19200	9955	21400	22100	22399
Max	2382000	2400000	2450000	2500000	2517000	2752000	2891800
Average	394795,417	407619,375	422037,104	413679,271	445928,833	468276,458	488915,667

Table 7. Statistical results of ovine livestock population from 2012 to 2017.

Ovine	2012	2013	2014	2015	2016	2017
Min	20387	22113	20691	19390	19341	15812
Max	2967300	3113500	3242760	3364460	3379000	3379500
Average	519343,875	553599,375	579326,875	585661,938	586166,375	591158,375

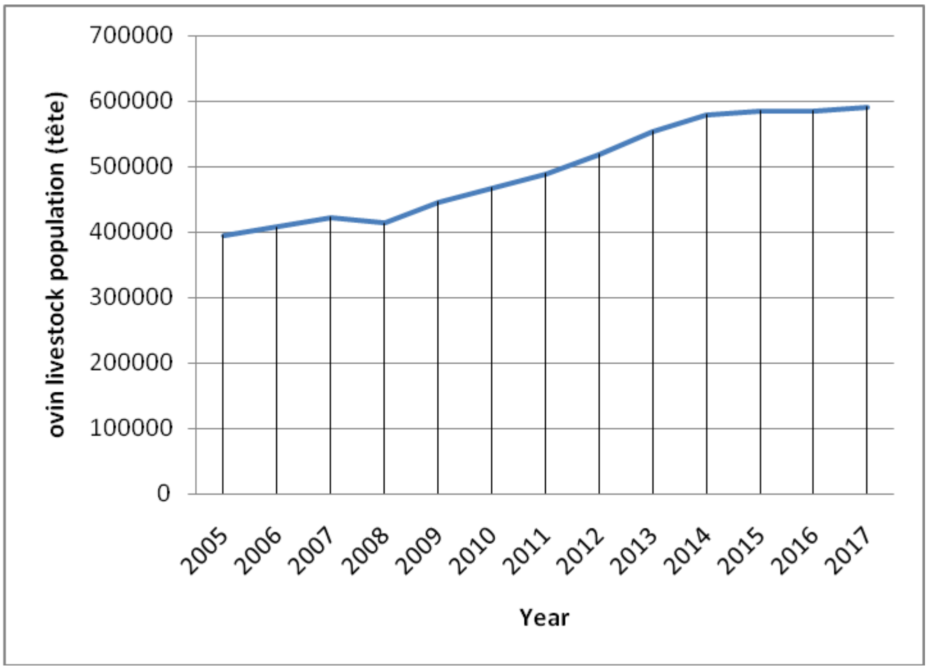

Figure 38. Average of ovine livestock population from 2005 to 2017.

Ovine population in Algeria show a slow increase from 394795,417 head in 2005 to 422037,104 head in 2007 and then it decrease to 413679,271 head in 2008 to go up after that until reaching its peak in 2017 (Tab. 6, tab. 7 and fig. 38).

b.2/ Bovine livestock population

Table 8. Statistical results of bovine livestock population from 2005 to 2011.

Bovine	2005	2006	2007	2008	2009	2010	2011
Min	0	0	0	0	0	0	0
Max	117700	119300	120554	122500	124400	126212	128027
Average	33043,125	33497,7083	34037,7083	34181,875	35050,6458	36410,4167	36944,9167

Table 9. Statistical results of bovine livestock population from 2012 to 2017.

Bovine	2012	2013	2014	2015	2016	2017
Min	0	0	0	0	0	0
Max	129827	132270	134180	161909	160602	156879
Average	38415,2083	39780,5208	42701,0833	44782,2708	43756,375	39481,7917

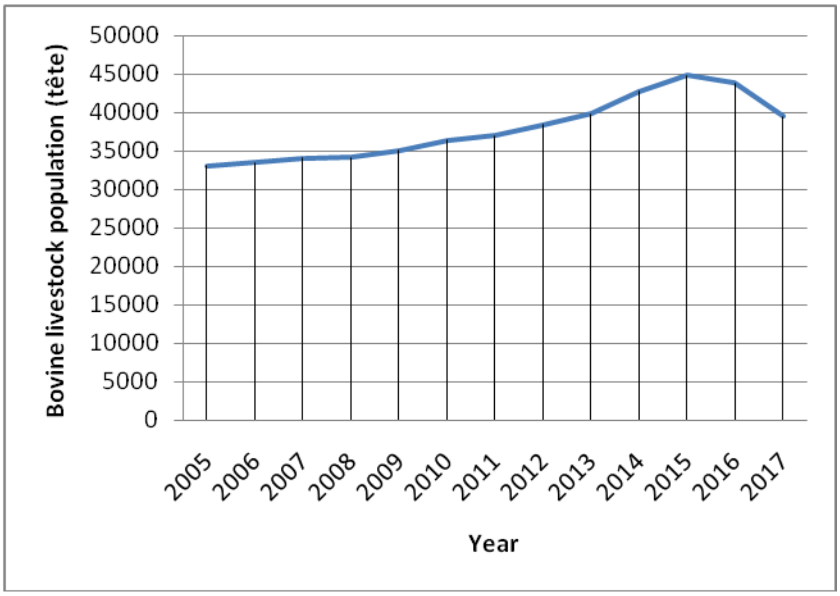

Figure 39. Average of bovine livestock population from 2005 to 2017

Bovine livestock population in Algeria shows a slow increase from 2005 to 2015 when it reaches the peak which was estimated at 44782 2708 heads, then it decreases to 39481,7917 head in 2017 (Tab. 8, tab. 9 and fig. 39).

B.3/ Caprin livestock population

Table 10. Statistical results of caprin livestock population from 2005 to 2011.

Caprin	2005	2006	2007	2008	2009	2010	2011
Min	940	1808	2344	2057	2395	2676	2475
Max	448695	490552	516588	448070	430000	1185330	484165
Average	74789,16667	78220,625	79955,4167	78153,3333	82544,1667	109932,125	91896,25

Table 11. Statistical results of caprin livestock population from 2012 to 2017.

Caprin	2012	2013	2014	2015	2016	2017
Min	2475	2900	2929	3614	2194	2468
Max	496132	526000	532000	540000	542000	498500
Average	95719,2708	101762,5	106871,646	104457,292	102806,271	103914,458

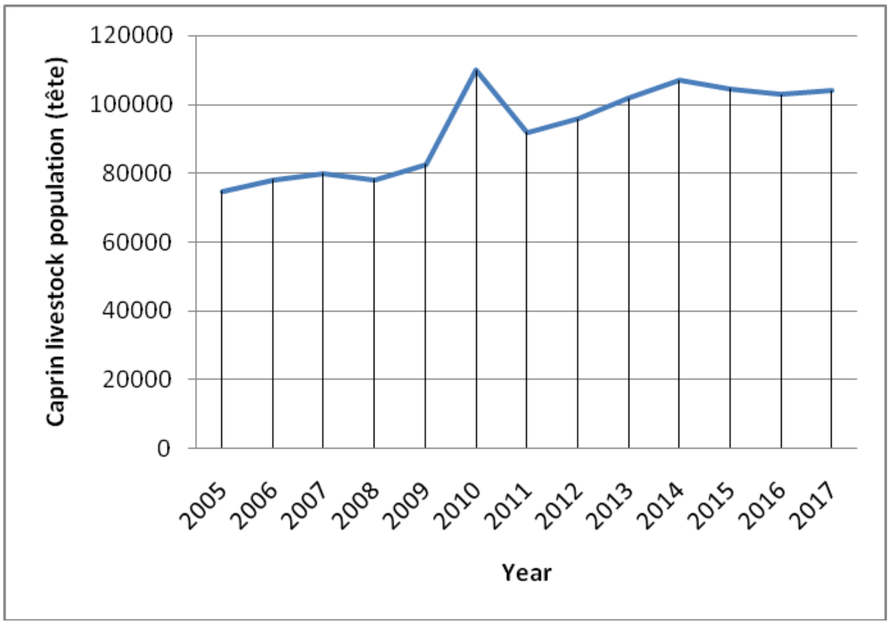

Figure 40. Average of caprin livestock population from 2005 to 2017.

Caprin population in Algeria notes many increases and decreases from 2005 to 2017 and 2010 was the year when the population reached its peak with 109932 125 head (Tab. 10, tab. 11 and fig. 40).

Table 12. Statistical results of ovine, caprin and bovine livestock population from 2005 to 2017.

	OV from 2005 to 2017	CP from 2005 to 2017	BV from 2005 to 2017
Min	21994,53846	2450,769231	0
Max	2872255,385	494058,8462	129832,6923
Average	496654,5337	93155,57853	37852,58814

The table 12, shows that the ovine population take the first place according to the number of head in Algeria with, an average of 496654,5337 followed by bovine population with an average of 93155,57853 head then, caprine population with an average of 37852,58814 head.

C/ PPR results

C.1/ Ovine PPR

Table 13. Statistical results of PPR in ovine in 2011, 2012, 2013, 2016 and 2018 respectively.

Ovine Cases	2011	2012	2013	2016	2018
Min	0	0	0	0	0
Max	65	2	6	4	569
Average	1,8	0,042	0,125	0,08	17,85

Table 14. Average of PPR in ovine in 2011, 2012, 2013, 2016 and 2018.

Ovine Cases	2011, 2012, 2013, 2016, 2018
Min	0
Max	114
Average	4

The tables 13 and 14, show that ovine PPR was present in Algeria in the years 2011, 2012, 2013, 2016 and 2018 where, have we recorded the largest number of cases with an average of 17,85 cases.

C.2/ Caprine PPR

Table 15. Statistical results of PPR in caprine in 2011, 2012, 2013, 2016 and 2018 respectively.

Caprine Cases	2011	2012	2013	2016	2018
Min	0	0	0	0	0
Max	20	17	26	3	62
Average	1,15	0,35	0,54	0,0625	2,83

Table 16. Average of PPR in caprine in 2011, 2012, 2013, 2016 and 2018.

Caprine Cases	2011, 2012, 2013, 2016, 2018
Min	0
Max	15,6
Average	1

Tables 15 and 16, show that goat PPR was present in Algeria in the years 2011, 2012, 2013, 2016 and 2018 where we recorded during the latter, the largest number of cases with an average of 2.83 cases.

D/ FMD results

D.1/ Bovine FMD

Table 17. Statistical results of FMD in bovine in 2014, 2015, 2017 and 2018 respectively.

Bovine cases	2014	2015	2017	2018
Min	0	0	0	0
Max	1009	1	95	120
Average	54,31	0,02	12,54	12,66

Table 18. Average of FMD in bovine in 2014, 2015, 2017 and 2018.

Bovine cases	2014, 2015, 2017, 2018
Min	0
Max	286,25
Average	19,885

The tables 17 and 18 show that bovine FMD was present in Algeria in the years 2014, 2015, 2017 and 2018. The largest number of cases was recorded in 2014 with an average of 54,31 cases.

D.2/ Ovine FMD

Table 19. Statistical results of FMD in ovine in 2014, 2015, 2017 and 2018 respectively.

Ovine cases	2014	2015	2017	2018
Min	0	0	0	0
Max	0	142	130	611
Average	0	3,291	5,5	110,68

Table 20. Average of FMD in ovine in 2014, 2015, 2017 and 2018.

Ovine cases	2014, 2015, 2017, 2018
Min	0
Max	197
Average	29,29

The tables 19 and 20, show that ovine FMD was present in Algeria in the years 2014, 2015, 2017 and 2018 where, have we recorded the largest number of cases with an average of 110,68 cases.

D.3/ Caprine FMD

Table 21. Statistical results of FMD in caprine in 2014, 2015, 2017 and 2018 respectively.

Caprine cases	2014	2015	2017	2018
Min	0	0	0	0
Max	0	0	14	57
Average	0	0	0,33	7,25

Table 22. Average of FMD in caprine in 2014, 2015, 2017 and 2018.

Caprine cases	2014, 2015, 2017, 2018
Min	0
Max	14,25
Average	1,896

The tables 21 and 22 show that caprine FMD was present in Algeria in the years 2014, 2015, 2017 and 2018 where, have we recorded the largest number of cases with an average of 7,25 cases.

V.2 Discussion

Livestock population results show that the sheep species constitute the most important percentage of animal wealth in Algeria followed by the goat species then the bovine species. This is due to several factors, including the geographical and climatic differences of Algeria, as well as the physiological differences and living conditions of each species.

For animal production results, It also corresponds to the number of livestock which itself depends on several conditions such as, the type of vegetation, climate ... ect. This reflect the rate of milk production in some regions like Setif, Batna.., which are rainfall and agricultural areas by excellence especially in the cultivation of cereals, which make these regions dairy ponds. Also, it reflects the rate of red meat production in Djelfa, Beyedh... and other regions which are provided with suitable conditions for sheep farming.

By comparing livestock's number and the cases of PPR and FMD, we deduced that cattle are more predisposed to FMD than other species. while for PPR, goats are the most predisposed animals and then sheep.

From the results of small scale we observed that most cases of FMD are localized along the main traffic highway, pastures and collective water points. so, we can estimate that directional distribution of the disease may be related to the transportation of animals from breeding areas, sharing grazing and drinking areas. It is also well known that biological, ecological and meteorological factors can influence the emergence of infectious diseases.

Algeria is a vast territory and there are obvious climatic differences between the different regions. Thus, weather conditions can also influence the transmission of the FMDV and PPRV. The specific factors that explain this directional transmission pattern need to be studied in more detail (He et al., 2015; Ma et al., 2017).

In the current study, the lack of information at the level of the Director of the Veterinary Office; which is the official institution mandated to have information on notifiable diseases in the country, was largely attributed to the lack of disease notification at the county level (Gok, 2015); leading to a breakdown of the already weak monitoring and reporting structure (Catley et al., 2012; Gok, 2014); that's what make as thinking to a new institutional reporting structure that will improve disease notification by the counties, which is a mobile and web-based disease information sharing platforms to facilitate and improve the sharing of livestock disease information and this is what the idea of VETALGIS web site aims for.

PPR and FMD outbreaks and cases were reported by the Ministry of Agriculture of the People's Republic of Algeria. As shown in the statistical result , the number of FMD outbreaks reported in 2018 was lower than the previous years, which is a reminder that more effective measures have been be implemented to prevent future outbreaks. The number of PPR cases is high compared to previous years, which means that there was some gaps at the level of the preventive system.

In fact, this study has revealed a great amount of information, particularly on the distribution and contribution of different species on disease transmission, between and within farms. But, it is difficult to determine to what extent these findings can be generalized to other situations, with different animals, livestock systems, livestock and human networks, climates and pre-existing levels of immunity.

The three main limitations constraining livestock disease control efforts in Algeria are the lack the lack of inclusion and correlation when planning livestock disease control programs, the under reporting and the luck of veterinary services and a powerless livestock identification system.

Limitation of the Study

The first difficulty faced was due to the under-reporting of the PPR and FMD epidemics at the county level. This affected the information available in the offices of the Director of Veterinary Services (DVS). Reports were only available for few (2014-2015-2016-2018 for FMD and 2011- 2012-2013-2016-2018 for PPR). Due to these limitations, maps of the spatial and temporal distribution of PPR and FMD outbreaks in Algeria could not be well generated, and show an heterogeneity in the analysis. The other challenge was to identify the areas to be included in the study, without official outbreak reports.

Conclusion and Recommendations

Conclusion

GIS represents a new technology in veterinary sciences which provides significant added value in animal health, by studying, reporting information and by modeling animal disease problems.

As routine data are usually taken into low consideration for either epidemiological or management purposes in veterinary sciences, a GIS can considerably increases the efficacy of communication to exploit those data. In the field of veterinary science, this methodology can be largely applied to touch different types of diseases and there are three situations in which it is suggested that GIS will play an increasingly important role in the future: the need to solve epidemiologically complex disease problems, the need for rapid surveillance of highly contagious diseases that could cross international borders, and the need to deal with politically sensitive diseases for which rapid and accurate notification is essential However, applying sophisticated spatial techniques to poor-quality data will not create an insightful investigation. The people working in GIS should keep in mind that maps cannot be an alternate for better data collection and recording. The maps will never be better than the original input data. It's a mere translation of information in a language which is easy to understand.

Impact of FMD and PPR is high for some regions but low for others. This impact varies according to the incidence of the disease and also the positive and negative impact of control measures. levels of access to veterinary services, animal health inputs and livestock markets.

GIS spatial analysis techniques have proven to be a useful tool that can support the decision-making process in planning, implementing and monitoring FMD and PPR control strategies in endemic and high-risk areas.

Recommendations

As a result of the above conclusion and points, the following recommendations are made:

- he relevant government body should develop and support the application of GIS in veterinary science in order to prevent and reduce the spread of diseases and their economic impact;
- The veterinary clinician and their staff should know how to use GIS in the office and in the field;
- It is strongly recommended that GIS tools and their application be used to produce maps for the selection of slaughter sites in urban areas of Algeria;
- There should be further studies using GIS techniques to monitor the evolution and distribution of animal diseases in Algeria, to detect the different problems and to solve them later in order to preserve public health and animal wealth in Algeria;
- The policies for livestock disease control should not be applied as general interventions, but need to be based on the ecological, social, cultural and economic context of the target communities;
- More investigators need to adopt the use of GIS spatial analysis techniques in the design, impact monitoring and development of control strategies for infectious livestock diseases;
- It is strongly recommended that the government strengthen prevention and control measures the sensitive areas, and that the export of animals and livestock products be strictly limited;
- Veterinary surveillance can reinforce by several actions implemented in the region, such as the geo-localization of holdings and the individual identification of all animals in the region;
- One of the main problems in obtaining the status of 'free zone with vaccination' is the maintenance of this health status, due to the permanent surveillance procedures required;

- As eradication of FMD is not predictable in many endemic countries, it is necessary to assess the cost-effectiveness of control if the incidence of the disease can be reduced by continuous mass vaccination;
- There is a need to explore opportunities to share GIS applications and innovations specifically focused on veterinary science;
- It also recalls that the restriction on the transport of animals from FMD-affected areas and high-risk areas needs to be reinforced;
- The application of GIS in veterinary science is progressing rapidly and it is necessary for every veterinarian to understand the basics of GIS. To support and advance the use of GIS in veterinary science;
- For those who use GIS in veterinary science, the potential of GIS applications in this field is recognized to be enormous. However, the community of users of GIS in veterinary science is rather small compared to other sectors;
- Due to the transboundary nature of FMD and PPR, a single country in an endemic area is unable to control and progressively eradicate PPR unless its neighboring countries share a similar objective. The Global Strategy also recommends the establishment of regional roadmaps for PPR. These strategies aim to reduce the PPR burden in endemic countries while developing strategies to prevent its entry into those;
- The following recommendations should take into account, as PPR control strategies in pastoral areas of Algeria should be adapted to specific geographical regions taking into account prevalent diseases of small ruminants, existing disease control practices, the socio-economic status of communities and access to veterinary services. PPR annual vaccination program should also include CCPP vaccination of goats as well as target animals aged 6 to 12 months. Policy makers should adopt the use of GIS and post-vaccine serological surveys to monitor the effectiveness and coverage of PPR vaccination campaigns in pastoral areas of Algeria;
- For endemic areas, it is necessary to examine the current impact of FMD and then to evaluate possible control measures, their effectiveness and cost. A cost -benefit analysis can then assess the impact over time when control measures either are in place, Benefits and costs will vary between groups over the long term of a control program.

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